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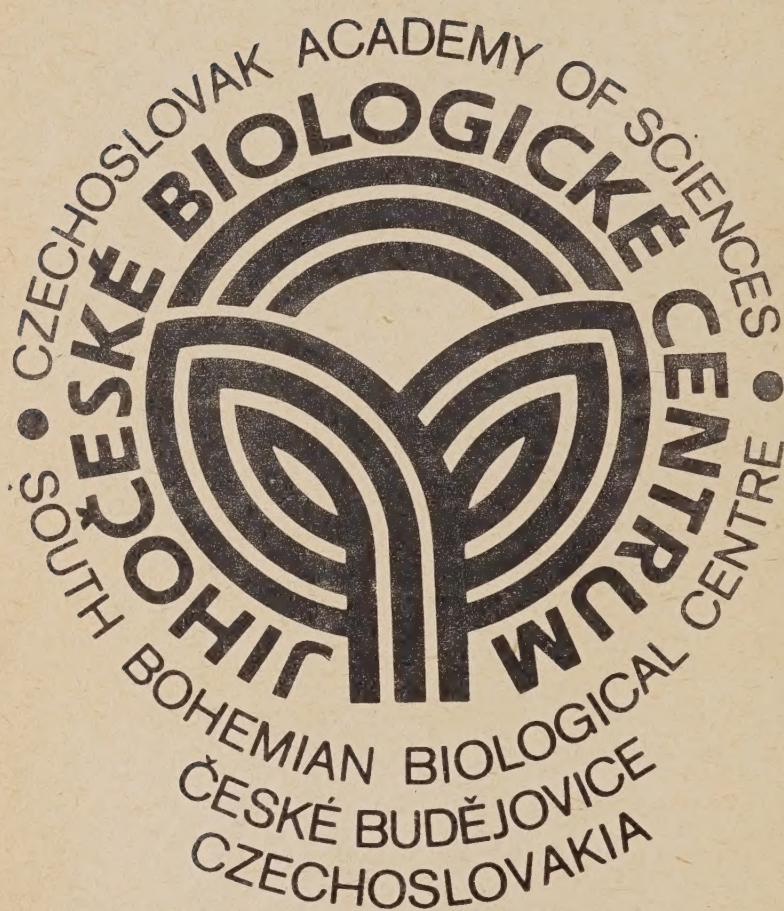
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BIOINDICATOIRES
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PROCEEDINGS OF THE 5TH INTERNATIONAL CONFERENCE

BIOINDICATOIRES DETERIORISATIONIS REGIONIS

ČESKÉ BUDĚJOVICE, MAY 23-27, 1988

EDITED BY J. BOHÁČ AND V. RŮŽIČKA

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Introduction

J. BOHÁČ

Ladies and gentlemen,

Let me welcome you to České Budějovice where the Vth International Conference Bioindicators Deteriorationis Regionis is just to start. We all know that the global ecological problems of our planet prove to be the most important problems at present. The control of admissible concentrations of pollutants in the environment as well as the recognition of their biological effects are inevitable. Laboratory test of toxic substances in organisms do not indicate their effects sufficiently as they do not show the effects on populations, communities and ecosystems. For this reason it is necessary to create a system of bioindicators which would demonstrate the complex biological response of organisms to environmental pollution. The instrumental measuring methods can hardly replace the method of bioindication the importance of which does not consist in measuring the parameters of environment but in investigating the response of biotic organisms to pollution. The importance of bioindication can be documented also by the fact that the projects on the research of bioindicators were embodied in numerous scientific projects, such as Man and Biosphere, International Union of Biological Sciences etc.

The MAB programme declares that in the study of ecosystems, it is necessary to use biological indicators independently of the physical and chemical analysis. The application of bioindicators has the following advantages: 1. They indicate the impact of all the individual environmental factors and of the entire environment, 2. The provisional assessment of biological impacts, by means of physical and chemical analysis, becomes unnecessary, 3. They indicate those sites within the biological system, where toxic and polluting matters accumulate.

We believe that atmosphere of cooperation will help the development of knowledge and of the bioindication method in ecological monitoring.

Thanks everybody for the participation and for the contribution to the success of the conference.

Theoretical principles of biomonitoring

V. MEJSTŘÍK, J. POSPÍŠIL

USE OF INDICATORS OF IMPACT

When all possibilities fails, ecologists involved in impact assessment studies may resort to the use of indicators as a means of obtaining some measurement of stress on natural system. This would normally be a fall back position in the ecological scoping process when the possibilities for studying the valued ecosystem components either directly or indirectly, are limited (DEANLANDS, DUNKIER, 1983).

The term indicator implies a movement of some variable away from a known set of normality, that is, it indicates that a change has occurred (INHABER, 1977). Indicators have received a lot of attention in the context of baseline studies (WESTMAN, 1985) and monitoring but, by definition, have limited use in predictive sense (COOPER, 1976).

The majority of the publications on bioindicators of impact are related to their use for monitoring water quality with old tradition (AVERETT, 1981). A report in the United Nation E. C. E. (1980) included a summary of bioindicators for monitoring atmospheric pollution.

Indicators of environmental stress have been developed for individual organisms, populations, communities and ecosystems (MEJSTŘÍK, 1986). BAKER (1976) provided an excellent summary of the range of species characteristics which should be considered in choosing indicator species (Tab. 1). The choice of an indicator species depends on its sensitivity to the expected perturbation and the degree to which its response is observable in space and time (without undue time lags).

The application of experimental biological methods in biomonitoring systems has several possibilities. Important problems to solve are among others:

1. To express the general state of pollution in air, water and soil environments.
2. To characterize qualitatively and quantitatively the biological processes in different environments and in different areas.
3. To evaluate the development in resources and to express their biological conditions as consequences of chemical and physical factors.

Tab. 1. A classification of indicator species (according to BAKER, 1976).

Type	Characteristics	Examples
Sentinel	introduced, sensitive	limpet, winkle, Spartina
Detector	indigenous, sensitive	limpet, lichen, crustaceans
Exploiter	competitive advantage when subsidized	Enteromorpha
Accumulator	bioaccumulate chemicals	shellfish, mosses, lichens
Bioassay organisms	sensitive, suitable for laboratory tests	shrimp, fish

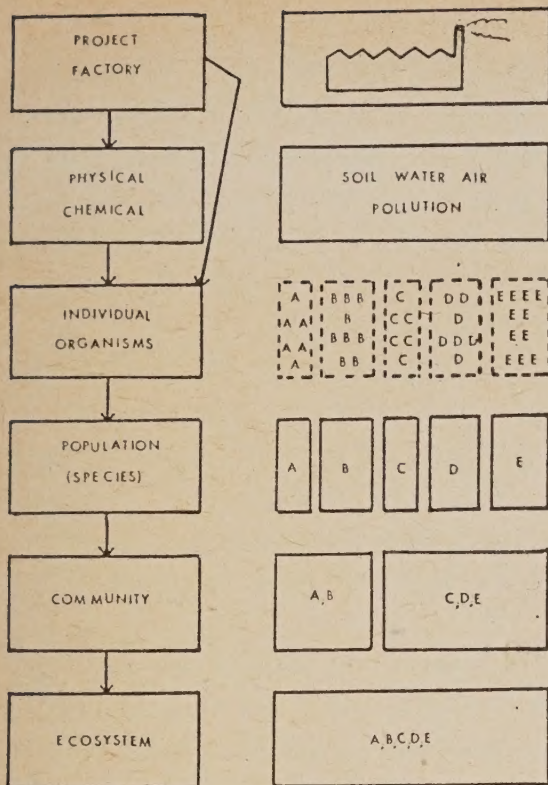


Fig. 1. Impact and structural relationships of biota.

ECOLOGICAL SCOPING AND BIOMONITORING

In ecology, we recognize that a population is a special assemblage of organisms of a species, that a community is an assemblage of species populations, and that the total biotic realm within an ecosystem represents either a community or an assemblage of communities, depending on how the ecosystem is defined and bounded. The framework (Fig. 1) is derived from a recognition that responses of biota, at any level of the ecological hierarchy, to perturbations are realized through some combination of responses at the level of individual organisms. From an impact assessment perspective, this mode of thinking is fundamental to two basic questions:

- at what biological level are the valued ecosystem components in this assessment
- at what biological level is it possible either to predict or detect the expected perturbation?

Unfortunately, the levels often do not coincide. The majority of concerns seems to lie at the population level - how will population X be affected by the project (man's activities)? Occasionally, the concerns are at the level for community or ecosystem; for example, a relict spruce community, peat bog community or forest ecosystem.

On the other hand, our ability to predict or measure changes due to human activities is often very weak at the level of population. This may be attributed to our lack of understanding of the mechanisms that control population variables, and partly to the extreme natural variability inherent in such variables. Our best chances for accurate prediction and for success in detecting changes (monitoring) may lie at the level of the individual organism

Descriptive biological methods are now increasingly used in the assessment of pollution. There are limited, however, by the difficulties of expressing numerical relationships between the characteristics of environmental quality and the biological conditions under various degrees of pollution to which resources are subject. Experimental approaches using laboratory and field methods are aids in the attempt to solve this problem.

In ecological monitoring initial baseline data collection programme would be used to characterize the situation in the real time. Case studies would be undertaken to predict how state variables will change as a result of the man-made activities, and, following start up of the approved activities, monitoring would be used to determine the actual impact conditions.

The main problem is a translation of these simple steps into a basic paradigm of monitoring as viewed by scientists.

(and perhaps to a limited extent at the community and ecosystem levels). In cases where it appears impractical either to predict or measure changes at the population level for a species of concern, it may be expedient first to examine the response of individuals to a man-made induced change and then attempt to extrapolate this individual response into response at the population level.

When we look again at our framework (Fig. 1) the first message is that the man-made action (project) usually acting through the physical and chemical environment, may have its first effect on biota at any (or all) of the levels of the food web. If the level affected coincides with the level of the species of concern, that the food-chain linkage is not implicated.

The biomonitoring is the quantitative method necessary to determine the extent to which human activity is altering the structure and function of natural ecosystems in different areas. In the broadest sense, monitoring is to understand the human impact on the biosphere itself. Much of the current monitoring effort seems to focus on the levels and distribution of contaminants, rather than on the environmental assessments from the standpoint of life-support functions, goods and services, and quality of life.

Monitoring to assess ecosystem status and trends falls into several broad categories:

1. In first class it is possible to measure the rate of destruction of certain ecosystem types. Obviously, pollution is not the only stress that affects natural ecosystems. So one kind of ecological monitoring is basically an inventory to determine the quality, distribution, and rates of loss of various ecosystem parts or types. This type of monitoring is fairly straightforward; it relies heavily on application of remote sensing.
2. A second class of ecological monitoring involves monitoring to assess the extent and significance of specific known contaminants or stresses, usually on a site-specific geographical scale. There are many special studies, conducted either in response to some specific regulatory or management requirement or for research purposes. If we have very special problems, such as the impacts of lead pollution on fish, techniques and monitoring are well developed. However, when we consider larger and open ecosystems, even these site-specific, problem-specific studies become quite difficult to design and interpret. Generally, as we moved toward looking at larger, more complex systems and toward more subtle or less devastating effects, our understanding of how to monitor and what is actually occurring in the ecosystem becomes much weaker.
3. The third category of monitoring is long-term monitoring to detect subtle changes or shifts in ecosystems, usually on regional or widespread areal scale (effect of acid rain).

The problem of monitoring of ecosystem status is most difficult when we have not even isolated a specific stress to worry about, when we want to monitor to know whether structures and functions are satisfactory ecologically or whether something is beginning to go wrong.

There are some difficulties in ecological monitoring programs:

1. It is the complexity and dynamism of ecosystems. Ecosystems are constantly in a state of flux, and they exhibit wide variability over space and time. It makes very difficult to detect signals until those signals (changes) become very obvious. The warning signs may be masked by the background "noise" of natural variability.
2. Some of the natural stresses on ecosystems are perhaps of a greater magnitude than human-induced stress (hurricane, volcano). So even when we do detect significant ecosystem

changes, we often have a hard time linking them to the causal mechanism.

3. Even if we can recognise that a change is resulting from human activity, we must answer how significant it is, is it important, irreversible, catastrophic? We know that there are many compensatory mechanisms in ecosystems and that ecosystems exhibit varying degrees of resilience. So even where we do detect that impacts are occurring, we sometimes have difficulties defining their real importance. Are they transient effects or unidirectional changes?

All this scientific complexity and uncertainty poses some basic problems in mounting research and monitoring programs to detect ecosystem change. If we are to better distinguish from among long-term, widescale ecosystem changes—those which are cyclic, those which are unidirectional, those which are natural, and those which are human-induced; than we must maintain some basic, long-term ecosystem studies. Now, we are in difficulties. As yet, virtually no funding mechanisms are available to support a program of continuing, long-term ecological research and monitoring!

S U M M A R Y

We are passing through a transitional "ecological period" not dissimilar to the "agricultural revolution". During that period society discovered that harvesting food from the unmanaged landscape did not deliver this resource in either sufficient quality or quantity to meet society's expectations. As a consequence, environmental and landscape management was undertaken to ensure that the delivery more closely approximated society's needs. Similarly, the unmanaged environment is no longer capable of assimilating technological waste without careful management (CAIRNS, 1979, 1981). Ecological monitoring is very important method which helps environmental and landscape management. The biological assesment and monitoring of disturbance effects will probably go through four developmental stages: 1 - awareness, 2 - observational, 3 - predictive, and 4 - managerial. These phase are not clearly demarcated, but we are now entering probably the predictive stage by attempting to estimate the hazard to landscape, environment and human health. Present practices have proven inadequate for both the prediction of effects and the validation of these predictions. As a consequence, we must ask what additional evidence is needed to improve our predictive capability, including of the validation of the prediction. Clearly, we are not using and developing presently available practical ecological monitoring methods on the scale that is needed for adequate environmental quality control and ecological scoping. Implementation of use can be accompanied by development of new methods of ecological monitoring.

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The current problems of ecological monitoring in biosphere reserves

A. GUSEV, V. BELIAKOV, J. BOHÁČ

The monitoring of global changes of the environment is one of the main reasons of the origin of biosphere reserves. They can serve as research background because they are relatively little influenced by human activities. They also conserve all ecosystem links in such condition which is not found in the surrounding artificial landscape. Bioindication is one of the principal methods of the ecological monitoring. The main advantage in bioindicational research is the fact that it reflects the complex biological reply to the influence of various factors in the environment. This reply is not discret but long-term. On the example of the Centralchernozem Biosphere Reserve we want to demonstrate the significance of bioindication method for the determination of optimal defense regime in steppe ecosystem as well as the way of using this method for the studies of some polluting matters influence, for instance radionuclides, on ecosystems and their components.

MATERIAL AND METHODS

The principal directions of the investigations within the ecological monitoring programme in the Centralchernozem Biosphere Reserve are demonstrated in Tab. 1. Various methods of investigations are used (pedological, climatological, hydrological, phytocenological, zoological and ecological). These methods are described in numerous monographs (ISRAEL, ROVINSKYI, 1977; UTECHIN, 1977; KRIVOLUTSKYI, 1985; POKARZHEVSKYI, 1985, and others).

The research of the influence of pollution on forest steppe ecosystem is accomplished by bioindicators - 50 plant and animal species. These species were selected according to subsequent criteria: 1. Width of areal, 2. relatively high eurytopy, 3. polyphagy, 4. relative stability of population density, 5. feasibility of research, 6. sufficiency of the mass for chemical analysis. The collection of biological samples started 6 years ago, and up to present have been about 5000 samples of soil, plants and animals stored. We made about 4000 chemical analyses of the main parts of plants and animals: seeds, vegetative organs, roots, litter, hair, skin, muscles, blood, brain, kidney, spleen, stomach, intestine, sexual organs, excrements, urine, horns, etc. Samples are stored in paper boxes or in polyethylen bags. The following chemical elements and compounds are watched: Hg, Pb, As, Se, Sn, Cd, Cu, Co, Ni, F, Cr, Mo, Fe, DDT, polychlorinated biphenyls, radionuclides (radioactive isotopes of Sr, Cs, I, U and Pl). The analyses of biological samples are made in collaboration with numerous institutes of the Academy of Sciences of the USSR and also abroad (e. g. in the Czechoslovak Academy of Sciences). Various methods are used for the analyses (AAS method for heavy metals, gamma spectrometer and radionuclide meter for radionuclides, etc.).

BOHÁČ J., ROŽIČKA V. (eds.), 1989: Proc. Vth Int. Conf. Bioindicators Deterioration of Region. Institute of Landscape Ecology CAS, České Budějovice, pp. 15-19.

Tab. 1. Principal directions of investigations of the ecological monitoring programme in the Centralchernozem Biosphere Reserve.

Ecosystem	Components	Parameters
Atmospheric air	Gas	Temperature, humidity, speed and direction of wind, polluting substances, radionuclides
Precipitation	Falls solid liquid	Quantity, basic cations and anions, mineral and organic substances, radionuclides
Water	Daywater ground water	Flow, water level, temperature, pH, mineral and organic substances, radionuclides
Soils	Pansoil	Temperature, humidity, water reserve, soil structure, pH, mineral and organic substances, radionuclides
Communities		Species variety, destruction intensiveness
Populations		Size, interpopulation structure, reproduction success
Specimen		Genetics, morphology, anatomy, development, behaviour, mineral and organic substances, polluting substances, radionuclides

Tab. 2. The principal characteristics of abiotic and biotic components in various regimes of the steppe (period 1986 - 1987). 1 - unmown steppe, 2 - yearly mown steppe, 3 - periodically mown steppe, 4 - pasture, 5 - burning.

Characteristic	Variants of the defense regime				
	1	2	3	4	5
Sum of soil surface temperature (May-August), °C	711.3	867.7	853.2	736.1	844.9*
Spring reserve of water in soil (April), mm	936.0	848.0	798.0	864.0	763.0
Autumn reserve of water in soil (October), mm	694.0	627.0	715.0	720.0	650.0
Quantity of bacteria, thousands/g	1017	1158	1026	1268	1069
Intensity of soil respiration, mg CO ₂ /kg of soil . hour	11.8	21.8	14.6	13.2	20.0
Activity of cellulose destruction in soil, (April-October, average for month), %	4.9	8.0	5.5	5.3	6.2
Proteolytical activity of soil (April - October, average for month), %	4.6	4.3	5.3	4.1	5.8
Humus content in soil layer 0 - 5 cm (May - October, average for month), %	11.4	9.7	10.0	10.5	10.4
Total phytomass, q/ha	86.0	68.3	58.6	78.6	36.9
litter, q/ha	49.2	24.7	41.3	42.7	18.1
Plant diversity:					
total	138	159	170	162	159
diversity/m ²	22 - 36	41 - 57	45 - 48	28 - 42	25 - 41
Insects abundance (May - October), ex./10 Barber pitfalls . 24 hours	98.0	70.2	103.8	33.8	26.0
Species diversity of epigeic insects	23	12	13	14	12
Biomass of epigeic insects (May - September), g/100 Barber pitfalls . 24 hours	11.3	9.7	13.8	7.4	3.5
Abundance of soil invertebrates (April - October), ex./m ²	400.0	271.4	225.7	288.6	156.7
Species diversity of birds, pairs/ha	2.1	2.0	2.0	0.9	1.3
Abundance of rodents, ex./m ²	0.16	0.03	0.03	0.05	0.03

RESULTS AND DISCUSSION

Use of ecological monitoring for the determination of the optimal defense regime in forest steppe.

The speciality of the Centralchernozeem Biosphere Reserve is the defense of natural steppe ecosystems in 5 various variants of the defense regime: absolute defense, i. e. unmown steppe, yearly mown steppe, periodically mown steppe (in 4 years period), pasture and burning regime. These defense regime originate from the historical and economic base and the traditional forms of the agriculture in this region. It is questionable which of these regimes is the most optimal from the view point of the originality of the steppe. The bioindication method can be used to answer this question.

The principal characteristics of various abiotic and biotic components of the steppe under the mentioned regimes are demonstrated in Tab. 2. The totally defended steppe is characterized by a higher quantity of litter. The accumulation of litter is caused by the low activity of microorganisms and by that fact that the phytomass is not abstracted by man. The strong layer of litter is the reason of lower temperature of soil through whole vegetation season. The humidity of soil is higher in the unmown steppe than in other variants of the steppe regime. Humus content is high (maximal value 11.4 %), because all plant remains are crossing to the detritus. The ecosystem of unmown steppe represents a type of closed circulation of matter and energy, the values of the input and output of elements are considerably lower than values of the run of energy inside the ecosystem. The strong layer of litter is beneficial for the origin of micro-mycetes. On the other side, this layer of litter restrains the occurrence and abundance of algae (62 000 ex./m² in unmown steppe again 181 000 ex./m² in mown steppe). Grasses are dominant plant species in the unmown steppe. The mesophytical characteristic of this ecosystem is documented by the predominance of eurymesophytes. The euxerophytes occur in minimal number. The unmown steppe is characterized by the occurrence of trees and shrubs. Soft hydrothermal regime has a positive influence on the soil invertebrates, particularly earthworms, isopods and millipedes. For example, the abundance of the isopod species Trachelipus rathkei is in average 3 times higher in unmown steppe than in other variants of the steppe. Species diversity of soil invertebrates and vertebrates is higher in unmown steppe than in other variants of the defense regime. Our research shows that the unmown steppe is a highly productive ecosystem with complicated structure of phytocenoses, high species diversity and wide species tolerance both in plant and animal communities.

The use of mowing and pasture (made from 1935) in other parts of the forest steppe was conditioned by the premise that the influence of wild ungulated and rodents was significant in the steppe ecosystem, and that mowing and pasture have a similar effect on steppe ecosystem as wild animals (PACHOSKYI, 1919). Are mowing and pasture the optimal regimes for the steppe ecosystem of eastern Europe, or are they not? After our opinion it is not so. The results of mowing and pasture consist in more intensive warming up the soil, and in increasing non-productive water vapour. The abstraction of the phytomass and subsequently of the mineral and organic matter is the reason of the opening of matter and energy circulation in mowing and pasture ecosystems (BASILEVICH, 1979). Humus content is lower than in absolutely preserved steppe. Wind and water erosion, disturbing the microrelief, heterogeneity of plant cover are

Tab. 3. The content of Cs^{137} in the components of forest steppe.

Component	Mass (kg/ha dry weight)	Cs^{137} (mCi/ha)
Soil (0 - 5 cm)	$2.5 \cdot 10^5$	$50 \cdot 10^3$
Plants	$10.0 \cdot 100^4$	$1.5 \cdot 10^3$
Litter	$6 \cdot 10^3$	$1.5 \cdot 10^3$
Invertebrates:		
Protozoa	10	$50 \cdot 10^{-2}$
Nematoda	5	$25 \cdot 10^{-2}$
Enchytraeidae	2	$10 \cdot 10^{-2}$
Lumbricidae	12	$50 \cdot 10^{-2}$
Microarthropods	15	$9 \cdot 10^{-2}$
Insecta	25	$15 \cdot 10^{-2}$
other groups	10	$5 \cdot 10^{-2}$
Vertebrates:		
Rodentia	1.5	$3 \cdot 10^{-2}$
Artiodactyla	0.35	$1 \cdot 10^{-2}$
Insectivora	0.5	$1.9 \cdot 10^{-2}$
Carnivora	0.05	$0.5 \cdot 10^{-2}$
Aves	0.2	$1 \cdot 10^{-2}$
Reptilia, Amphibia	0.1	$1 \cdot 10^{-2}$
All animals	80	1.7 (0.003 %)

characteristic of the pasture and mowing in the forest steppe. The release of ecological niches after mowing and pasture are the reason of the polydominance of plant communities, their high species diversity (41 - 57 species/m²) and abundance (1662 - 1830 ex./m²). Pasture has a specific influence on the steppe ecosystem: extinction of litter, reduction of species diversity and productivity, absence of many species of plants and soil animals. Besides these facts it is known after archeological data back to historical period, that in forest steppe there prevail great mammals, which live in steppe only sporadically (elk, roe deer, wild boar). The abundance of typical steppe mammals (wild horse - tarpan, saiga) was much lower than that of other mammals (TSALKIN, 1963).

Natural periodic fire in forest steppe (once in the 4 - 5 years' period) is normal in the Eastern Europe. Fire reduces the phytomass maximally by 50 %. The temperature of soil surface (0 - 10 cm) increases maximally by 4 - 6°C. Fire has minimal influence on soil fauna, reptiles and small mammals. The negative influence of fire was registrated on some phytophagous insects only. The ecosystem quickly restores after the fire in all its functions to the stage similar to the absolutely defended steppe. The burning has a positive influence on the root system. After our opinion, it has a positive influence on the steppe ecosystem, and the absolute defense regime with periodical fire seems to be near to the optimum. Mowing and pasture are the historically originated regimes typical for the period of the exploitation of this zone by man.

Use of bioindication method for studying the pollution of ecosystems in forest steppe.

The Centralchernozen reserve is situated in the region of intensive agriculture near the industrial town of Kursk. The main factors of the pollution in the reserve are pesticides, fertilizers and heavy metals. The complete notion about the migration of some radionuclides

from global fallout in forest steppe ecosystems was found (BOHÁČ, KRIVOLUTSKYI, ANTONOVA, 1988). The content of Cs^{137} in the components of forest steppe is demonstrated in Tab. 3. The Cs^{137} content in the zoobios is mainly defined by high capacity of Cs^{137} , particularly in soil rich in particles and containing a lot of organic material. On the other side, invertebrates, especially with high biomass (earthworms, nematodes, Protozoa, and others) accumulate about 96 % of Cs^{137} . This high concentration of Cs^{137} in soil invertebrates is caused by trophic relations. The main part of soil animals consuming litter swallow with plant debris various microorganisms and fungi, which are significant source of some aminoacids for them. Radionuclides, which are accumulated by microorganisms and fungi from the litter, are inaccessible for plants, and they fall to trophic chains mainly through soil animals. The ratio between the content of Sr^{90} in the components of forest steppe ecosystem is similar as at Cs^{137} . In this case the content of Sr^{90} is slightly higher in vertebrates which have a higher ash content. The Sr^{90} is also accumulated in the skeleton of vertebrates.

This research has a great significance because the results can be used as background by long-termed monitoring of the radionuclides pollution in the USSR (e. g. after Chernobyl accident).

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Remote sensing of bioindicators of deterioration sites

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Plant indicators are the most evident keys for ecological site evaluation. We use the different plant indicator features - phytocenotical, morphological, physiological, biochemical, phenological, etc. (VINOGRADOV, 1964). Then, the analysis of these plant indicator features on aerial and space photographs permits to recognize the ecosystem sites, and its deteriorated modifications caused by various antropogeneous agents, air pollution especially (VINOGRADOV, 1981, 1982). Within this problem a main task should be studying the optical properties of injured plants (on the individual level) and ones of deteriorated sites (on the ecosystem level).

OPTICAL PROPERTIES OF INJURED PLANTS

Spectral reflectance measurements of a green vegetation cover reveal four damage classes, which could be used as bioindicators of air pollution conditions (MURTHA, 1978; VINOGRADOV, 1982).

On the low stage of injury when phenotypical changes in spectral reflectance are very slight. These low phenotypical modifications are slightly lighter, no more. The normal growth and typical spectral reflectance are restored quickly after stopping of antropogeneous influences.

On the middle stage of injury with incipient damage spectral reflectance of leaves is increased over the all visual spectrum weekly, and is dropped over the near-infrared spectrum strongly.

On the high stage of injury after period of chronic damage it causes chloroplast deterioration. Spectral reflectance is increased over the orange-red, and leds a green to red shift with the maximum reflectance in the yellow.

On the final stage dead red-brown foliage and leafless trees led further shift spectral reflectance toward the red as well as a noticable increase in the level of the red reflectance. Finally, aindry injured foliage is highly reflectance of the near-infrared. It should be remarked that the middle-infrared radiance and microwave brightness of high damaged plants is decreased in contrary.

Analysing spectral reflectance features of damaged plants permit to reveal the range classer of injuries using multiband photographs (HILDEBRANDT, KENNEWEG, 1986; FRITZ, PENNYPACKER, 1975; NAGEL, 1984). For example, oak leaves damaged by powder mildow increase spectral reflectance in the visible by 0.08-0.12 with a sufficient optical contrast between health and damaged leaves near 0.25-0.28. But in the near-infrared they increase spectral reflectance more slight only by 0.04-0.05 (VINOGRADOV, SOSHNINA, et al., 1988). Thus, injuries caused by powder mildow are high different from somatic damaged by very insignificant rise of reflectance in the near-infrared whereas are like in the visible (Fig. 1).

OPTICAL PROPERTIES OF DETERIORATED SITES

The phytocenotic bioinicators of deteriorated sites as they are viewed from above decrease the phytocenometric features such as: plant projection, density, high, fidelity, productivity

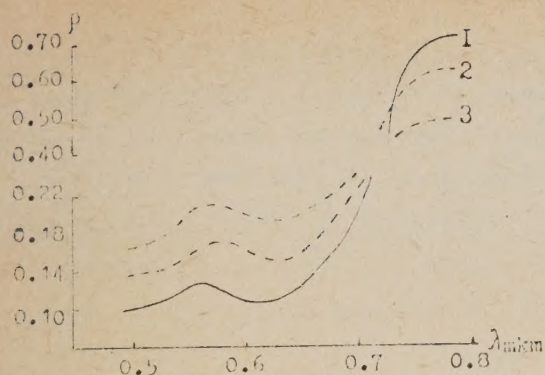


Fig. 1. Spectral reflectance (ρ, λ) of oak health leaves (1), leaves damaged by powder mildew (2), and leaves damaged by disease (3) as function of plant deterioration.

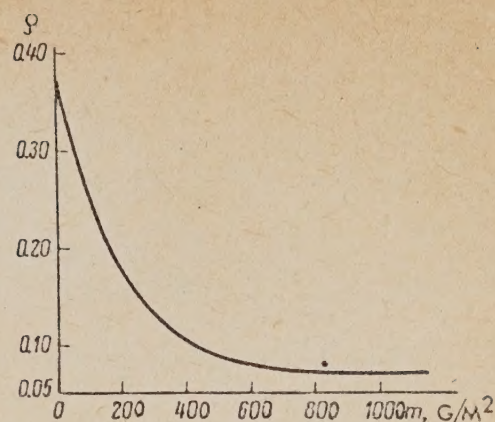


Fig. 2. Reflectance (ρ) v. s green above ground biomass of grassagebrush vegetation (m) as function at deterioration of plant cover.

and decrease soil quality features such as: humus content, fertility, water supply (VINOGRADOV, 1987). Spectral reflectance changes caused by deterioration of vegetation cover are described by a certain mathematical equations. For example, decrease of above ground phytomass during long-time of rangelands caused by overpasture leads to increase of spectral reflectance in the orange-red and decrease it in the near-infrared. This interrelation between reflectance in the orange-red (ρ) and green above ground phytomass (m) is described by exponent function:

$$\rho(m) = \rho_z + (\rho_0 - \rho_z) \exp(-\alpha m),$$

where ρ_z - is ρ of optically dense vegetation cover, ρ_0 - is ρ of bare soil, α - is parameter of degree influenced by vegetation and soil formation.

For example, in a subarid region with light coloured soils the natural dense green vegetation cover with phytomass 400-600 g/m² have low orange-red reflectance 0.08-0.10. On the first stage of deterioration range phytomass is decreased to 300 g/m² with reflectance 0.12-0.14. On the second stage of deterioration caused by overpasture reflectance raises to 0.16-0.18. On the third stage of deterioration with very low phytomass less than 100 g/m² and exposition of bare soil reflectance reaches 0.22-0.24. Finally, very rare vegetation and bare subarid soils have a high reflectance 0.30 and more. Such ranking optical of deteriorated sites permits a machine processing of aerial and space photographs for mapping of deterioration stages (Fig. 2).

REMOTE SENSING OF THE DYNAMICS OF DETERIORATION SITES

A comparison of aerial and space photographs taken at the different years permits to monitor the dynamics of deterioration sites. The time interval between repetitive aerial and (or) space surveys depend on the rate of area changes of deteriorated sites: the moderately dynamics landscapes are deteriorated by 1 % and less of the whole area in year should be surveyed one time for 5-8 years, the middle ones - by 1-2 % - one for 3-5 years, and the

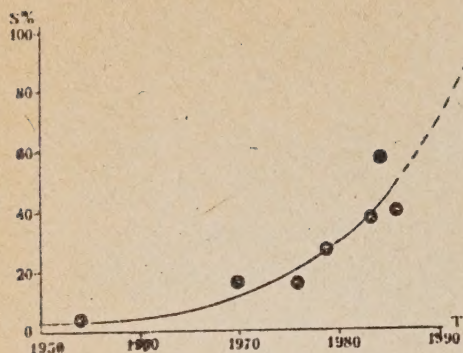


Fig. 3. Dynamic trend of area expansion of drift sands (S) over Kalmykin subdesert during 1954-1984 and prediction trend to 1994.

high ones - 3 % and more - one time for 1-2 years.

A comparison of repetitive aerial and space photographs reveals the non-linear trend of space-distributed dynamics of the area of deteriorated sites. Such deterioration trend of area change (Y) could be tracked during a long time interval (X) to 50-100 years and may be described by the Homperetz equation:

$$Y = a / (1 + \exp(-\alpha(X))),$$

where a is the maximum possible area of deteriorated site in the recent stress conditions, α is the parameter caused by the rate of area change. But we are working within a short intervals of 10-30 years and are dividing this trend on the some stages.

On the start stage under the acceptable limit of antropogeneous press the expansion of the area of deteriorated sites is slight through the ecological compensation and ecosystem stability.

On the middle stage over the acceptable limit of antropogeneous press the expansion of the area of deteriorated sites is accelerated. Such deterioration trend is described by exponent function:

$$Y = a \exp(\alpha(X)).$$

For example, in the Black Lands Region, Kalmykian Republic, USSR, by repetitive aerial and space photographs during 30 years from 1954 to 1984 the expansion of the area of such deteriorated sites as drift sands caused by overpasture of rangelands is approximated by equation

$$Y = 2.3 \exp(0.1(X))$$

(Fig. 3) (VINOGRADOV, LEBEDEV, KULIK, 1976). In the other region, Vitosha, Bulgaria, during 50 years from 1930 to 1980 the expansion of the area of deteriorated sites caused by forest cutting is approximated by equation

$$Y = 0.7 \exp(0.05(X))$$

(BONDEV, YANEV, 1981).

On the final stage the destructive succession the expansion of the area of deteriorated sites is attenuated. Such trend of the area change is formed by exhaustion of the natural land reserve of by land amelioration, and may be described by exponent function also:

$$Y = a (1 - \exp(-\alpha(X))).$$

Such attenuated trend is observed, for example, during the monitoring with the repetitive space photographs from Landsat of the expansion of the area of deteriorated sites damaged by air pollution of forest ecosystems around the iron sintering plant at Wawa, Ontario, Canada, after 1972 (MURTHA, 1974, 1978).

Using the revealed trend of the area change of deterioration sites we could extrapolate the change tendency on the near future at 5-20 years forward. For more complex land system where we deal with a number of deterioration agents we could use a system of differential equations described the area changes for each classes. In this case the error relative of the area change prediction may be 10 % of the area change.

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Generalization of global monitoring data according to the knotty-cell division of the terrestrial ecosystems

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Monitoring as a system intended for the measurement of environmental parameters faces considerable difficulties arising from the diversity and unsteadiness of these parameters "frozen" into the geographic environment, which itself varies significantly in longitude, latitude, and altitude. This three-dimensional diversity of the existence conditions is further complicated by the mosaic structure of soil-geological conditions and the superimposed mosaic of anthropogenic zones.

In dealing with such a diversity, we obtain a great variety of data, which have been accumulating for about 30 years. The amount of information is very large (especially, taking into account a vast bank of space information); we simply sink in the sea of facts, which, however, does not bring the solution of the problem nearer. Apparently, the most urgent problem at the present step of development of the global monitoring is to try to understand and process the data available rather than search for new facts.

The primary information about the state of environment and, in particular, its pollution (even such as the concentrations of the main anthropogenic toxicants in air, soils, plants and animals of various systematic groups) is very diverse and heterogeneous. It is dispersed over a great number of literary sources and various reports and can be understood only by specialists.

To make it possible to use these data further for such purposes important for national economy as ecological examination, estimation of ecological costs of designs, estimation of ecological risk and expenditure, ecological forecast, ecological planning (including territorial-economic, social, recreational, sanitary-hygienic, etc.) it is essential to have a small number of generalized, statistically significant indices, which could characterize the pollution field of the country and which could be turned over to the planning and economic organizations of various levels for practical use. The generalization of data is, therefore, the major problem.

Primary data generalization of various levels may be employed depending on the objective.

The rigorous scientific approach involves fixation of the presently existing diversity (1st level); unification of the primary data for individual regions (districts, territorial-industrial complexes, republics) (2nd level) or natural zones of the country (3rd level) is also possible. In the framework of global monitoring it is reasonable to integrate data for individual countries (4th level) and continents as a whole (5th level). Also considered are the semiglobal (6th) and global (7th) levels (ROVINSKY, 1982).

Though the pollution field of the country is a complex mosaic, the distribution of anthropogenic zones, with which the impact of the anthropogenic pollution on biosphere is which are knots (cities and industrial zones) connections (main roads) which tend to be related to industrial and agricultural production and cells which are confined by these connections and where the biosphere is relatively little disturbed.

To obtain average pollution levels, to which the bulk of population is subjected, summation must be taken with respect to the knots and cells of the above knotty-cell structure of the anthroposphere. In calculating the arithmetic mean, however, it would be incorrect to assign a statistical weight of unity to each summand. To take into account the actual structure of population, each value should be assigned the weight of relative population in the corresponding knot or cell:

$$C_b^p = \frac{1}{n} \sum_{i=1}^n \frac{d_i}{D} \cdot c_i$$

where C_b^p is the toxicant background concentration reduced to population for the whole region; c_i is the toxicant concentration in the i -th province (knot or cell); d_i is the population of the i -th district; D is the total population of the region. With this approach used for calculating the toxicant background concentration for a country, the Yakut Republic would contribute much less to the resulting value than the Donbass; this reflects the actual situation (for people) more correctly. Data for such calculations are available.

To establish the conditions of crops growing or biomass and oxygen production by plants, account in summation should be taken of the statistical weights of plant biomass:

$$C_b^p = \frac{1}{n} \sum_{i=1}^n \frac{b_i}{B} \cdot c_i$$

where C_b^p is the toxicant background concentration for the whole region reduced to plant biomass; B is the total plant biomass of the region; b_i is the plant biomass of the i -th district (here, a cell).

The background concentration of a toxicant for crops so calculated would obviously be smaller than the value for people and greater than for wild vegetation. This is quite natural and reflects the actual situation in any region more correctly.

Of particular interest for evaluating the state of environment in cells is to calculate the background content of main toxicants averaged over the cells in animals and, especially, in mammals. The point is that the influence of industrial environmental pollution on man cannot be objectively assessed by studying man himself, since the share of locally produced food is not large under the conditions of the present-day centralized supply and developed intra- and international economic integration. And if, in addition, one takes into account the common use of a great number of drugs it will become clear that the microelement composition of human body (say, of its excretions) is inadequate to the local level of industrial pollution in each particular region.

Studying the content of toxicants in such components of the environment as soils, water, and arboreal vegetation also fails to solve the problem. This is primarily due to the total toxicant content in water or soil being not equal to the amount entering the human body on account of the difference in the migrating ability, biological activity, assimilability, and forms of existence of toxicants in human body and various media. Another reason is that the analysis of such "inert" objects as soils, water, and arboreal vegetation gives data integrated over years or even decades (soils) or over a vast region, such as the catchment basin for river waters.

The advantage of animals-bioindicators (especially mammals) is that they reflect the current state of biogeocenoses more adequately and can reflect the pollution dynamics of the latter.

In addition, the enzyme mechanisms of numerous vital metabolic processes are similar in man and animals. The enzymes are known to be inhibited and activated by heavy metals coming from the environment, to which they are disposed from industrial enterprises. Thus, for detecting pollution levels hazardous for human health, the evidence on the content of heavy metals in mammals is most important.

The summation is performed, in terms of the following correlation:

$$C_b^a = \frac{1}{n} \sum_{i=1}^n \frac{m_i}{M} \cdot c_i$$

where C_b^a is the toxicant background content for the whole region reduced to the biomass of a particular animal species (e.g. elk); c_i is the toxicant content in the body (e.g. in the liver) of an elk from the i -th district; m_i is the elk biomass (population) in the i -th district, and M is the total elk biomass (population) in the region.

At present, the populations of the main animal and bird groups are regularly estimated virtually all over the country, and the data for such estimates as well as those concerning the biomass of the main plant communities are available (see SMIRNOV, 1971 and related papers). Thus, the approach described allows a considerable body of experimental parameters to be transformed into a small number of generalized parameters suitable for further practical use.

We believe that further development of this approach must involve investigations in several directions:

1. Refinement and detailing of the knotty-all structure itself, when some connections may be rejected in the course of the study as insignificant, while a number of new ones can be revealed. Thus, the highway sections with the traffic intensity exceeding 1000 cars per hour and with waste gases spreading over as far as 3 km (POPOVA, 1983) should, apparently, be included into anthropogenic zones (knots of the network) whereas the sections with the traffic intensity of less than 100 cars per hour should be included into background zones (cells).

2. Development of methods for discriminating background and anthropogenic zones.

We have suggested that such determination should be carried out in terms of the criterion of plant community vertical (story) structure integrity (BUTUSOV et al., 1985).

3. Development of methods for interpretation of space photographs of anthropogenic and background territories since this is the only means of investigating the entire territory of land so far.

4. Defining the concept of the present-day pollution background.

Referred to as the present-day pollution background are the mean values of toxicant concentration affecting the bulk of plants, animals, or population of the region under consideration. Thus, it is correct to speak of the present-day pollution background of the Yakut Republic, Moscow with suburbs, European part of the USSR, or the USSR and Europe as a whole. Such understanding fits best Dal's definition: "Background ... general colour on which the pattern is superimposed" (DAL', 1955). "No matter how considerable are the elevations in local zones, they do not directly figure in the background value" (ROVINSKY, 1982). In addition, individual, more pure regions are singled out from the background, which can serve as standards.

It should be borne in mind, however, that all biocenoses are in some or other way affected by the man's economic activity. Anthropogenic toxicants falling from atmosphere and found even

in the places where the foot of man has never stepped. Hence, the present-day pollution levels of these purest regions should be correlated with the system of the present-day background values though they also do not directly appear in the background values.

The concept of the present-day pollution background should be distinguished from that of the original background, the latter characterizing the period prior to the beginning of the intensive economic activity of man. Such data are obtained through the analysis of buried media, such as age-old ice, bottom sediments, paleosamples, and materials from collections (NIKANOROV et al., 1985). These values are to be accepted as the criteria of biosphere purity (STEPANOV, 1985).

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Natural environment quality: populational criteria

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Bioindication of the natural environment quality in present day conditions presupposes evaluating the state of biological systems on population and ecosystem levels. Certain integral characteristics should be determined which would reveal the state of a population or an ecosystem as a whole.

Our case concerns the reaction of small mammal populations to environmental technogenic pollution. Seasonal cyclicity and age and functional structure of such populations cause differences in levels of toxicants accumulated in various groups of animals and diversity in toxic effects.

Unlike other anthropogenic impacts during technogenic pollution, the toxic effect can be directly measured from concentration of toxicants in total organism or separate critical organs and tissues (body burden).

Distribution of animals for toxicant concentration in body is proposed as a populational "body burden" measure, the integral distribution in total population being a combination of distributions in individual ecologo-functional groups (Fig. 1). Thus, the introduced term "body burden" is directly related to the most important populational parameters that regulate population density, its sex and age structure.

Earlier proposed mathematical models of some toxicants exchange in an animal organism permit calculation of their concentrations in a small mammal population by simulating its living conditions (Fig. 2).

The following conditions were taken into account:

- toxicant content in vegetation,

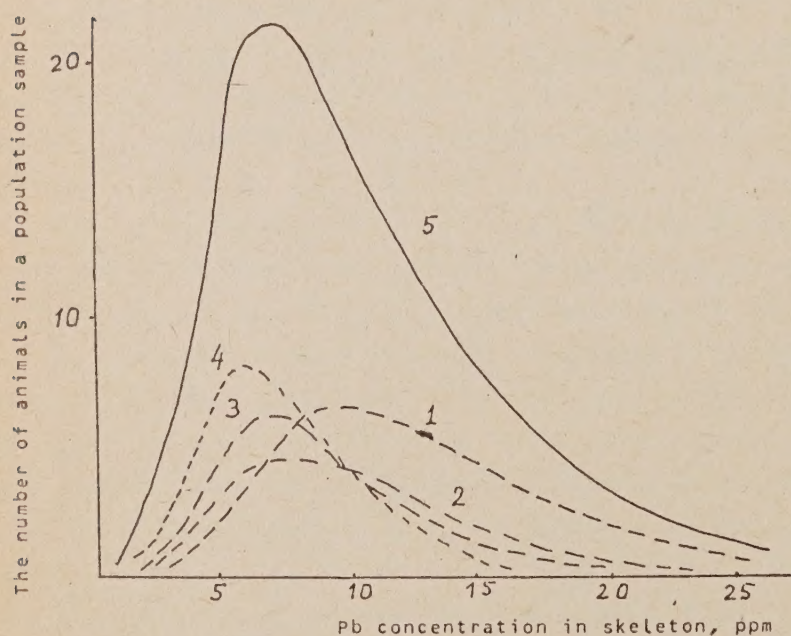
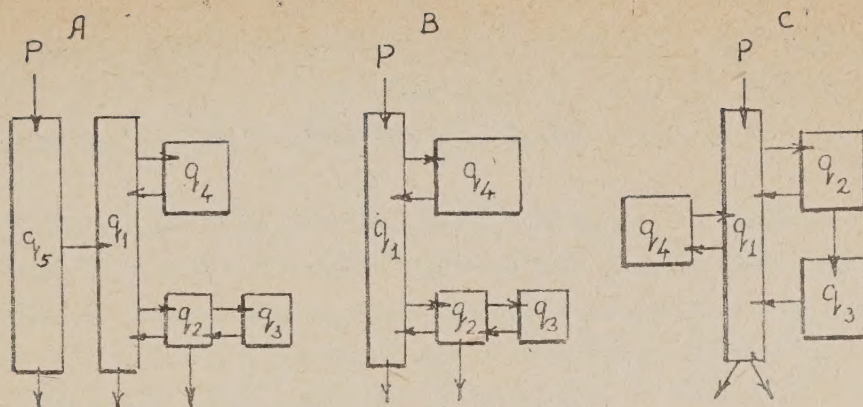


Fig. 1. Distribution of animals according to the Pb concentration in skeleton.



$$\dot{q}_i = \sum_{j=1, j \neq i}^N K_{i,j} q_j - \sum_{j=1, i \neq j}^N K_{j,i} q_i + P$$

Fig. 2. Mathematical models of metabolism

Methylmercury (A): q_1 - quantity elements in blood; q_2 and q_3 - in kidneys; q_4 - in the other organs and tissues.

Unorganic mercury (B): q_1 - quantity of elements in blood; q_2 and q_3 - in kidneys; q_4 - in the other organs and tissues; q_5 - total quantity of methylmercury in body.

Lead (C): q_1 - quantity of elements in blood; q_2 and q_3 - in skeleton; q_4 - in the other organs and tissues.

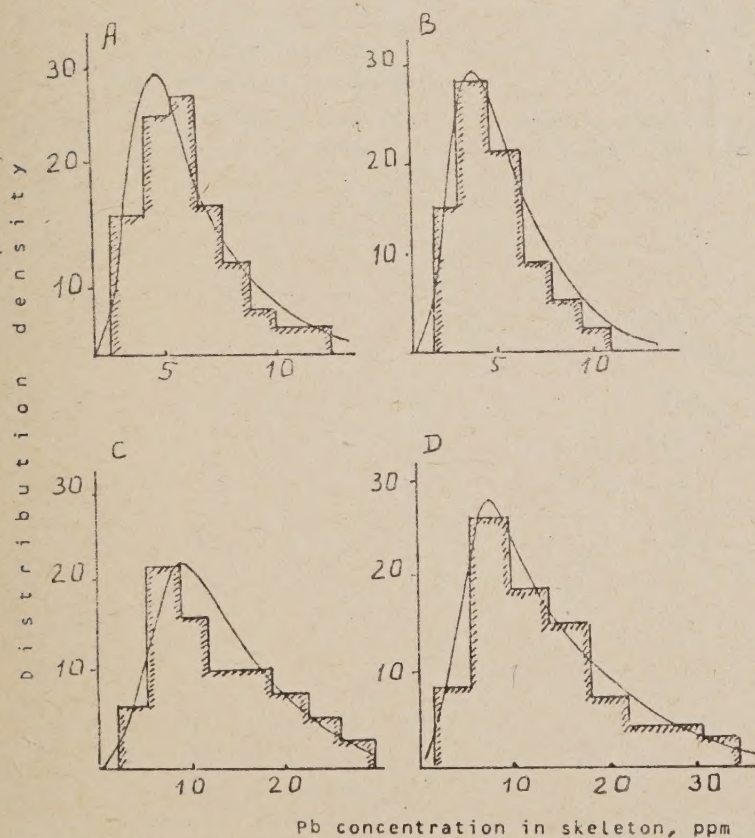


Fig. 3. Distribution of males (A) and females (D) of the red vole from the South Urals area according to the lead concentration in skeletons. Pooled samples from the North Urals areas (C, D)

- animal ecology: species composition of diets, toxicants content in food, daily penetration of toxicants through the intestine wall,
- peculiarities of toxicants exchange in animal groups differing age, weight, specific food consumption, etc.,
- simulation adequacy was tested on the red voles sampled in the North and South Urals.

The introduced estimate "body burden" permits evaluating the state of a small mammal population. On one hand, this evaluation should be based on a combination of physiological, functional, biochemical characteristics which reveal the state of an organism (from which the critical content of a toxicant in an organism is estimated). On the other hand, it should

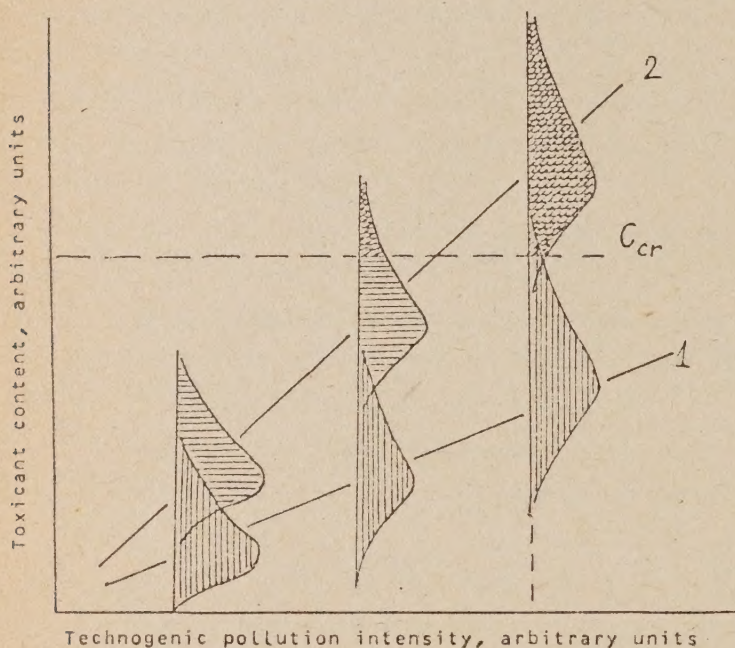


Fig. 4. The content of toxic elements in immature (1) and mature (2) small mammals from natural populations as dependent on environmental pollution intensity. C_{cr} - the critical level of toxicant
 the proportion of injured animals.

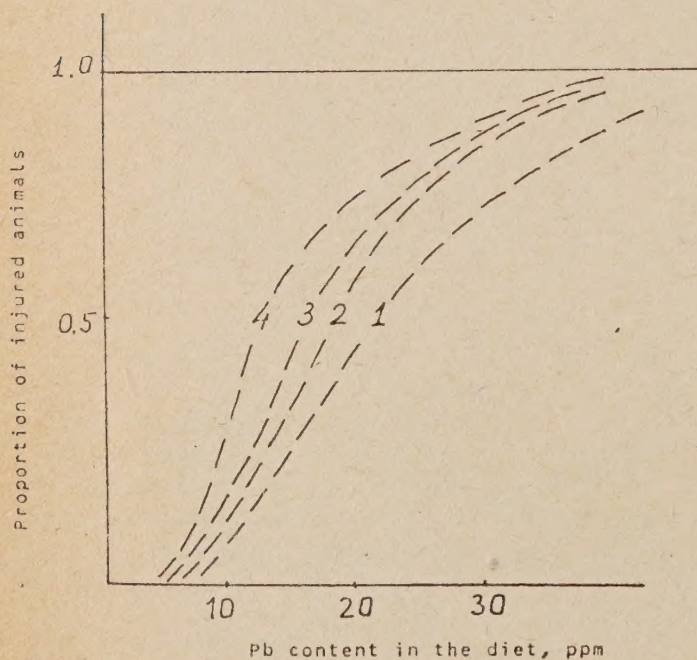


Fig. 5. Sensitivity of various intrapopulation red vole groups to lead.
 1, 2 - mature females (1) and males (2).
 3, 4 - immature females (3) and males (4).

reveal the state and viability of the population. Analysis of toxic effects of the majority of pollutants ~~eroids~~ ^{eroids} suggests that the central nervous system and reproductive functions are injured primarily. Ultimately the resulting decrease of life-span and fertility of animals determine the future of the population. The state of the population is dependent on the number of injured animals.

The percentage of animals with toxicant content exceeding C_{cr} depends on the environmental pollution degree. This percentage is different in individual ecologo-functional groups and in the whole population (Fig. 4).

Thus, evaluation of the state of natural populations of small mammals should be carried out in the following sequence: toxicants content in diets-toxicants distribution among animals in a population and the groups-percentage of injured specimens (Fig. 5).

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Graphic analysis of correlation structures with applications in ecology

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The currently expanded use of computers in routine research opens up formerly nonexistent possibilities for the study and prediction of behaviour of complex biological systems. This pertains first of all to the rapid, reliable and economical processing of large systems of data and phenomena, as well as to the use of exacting mathematical methods and simulation models even in the smallest laboratories. This corresponds to the needs of the present extensive and intensive approach to ecological studies and to the requirement for a rational and effective protection of the environment.

Currently important for the methodology of biomonitoring is the prediction of the development of the environment and to find simple relevant indicators as reliable evidence. It is no longer necessary to demonstrate again and again the toxic impact of some substances and the hazard of some localities, of which even the lay public is aware, while collecting evidence the situation further deteriorates. At present biomonitoring must first of all compare and control the intensity and development of changes in ecosystems, propose specific solutions for the given state and not just prove that these changes do exist.

With the application of multidimensional analyses of results the risk of a simplified view on the nature of complex phenomena is greatly diminished. Methods of multiple regression, the use of which was restricted in the past due to demanding calculations, form today basic program software of even the most simple pocket computers. At the same time a number of workers have no greater knowledge about the principles and limits of statistical procedures than they had before the use of computers. Procurement of a program often even reduces the user's interest to grasp the computer process and logic of the method. Thus the thesis "our computer says" often becomes a magic formula against all questions and reservations to the presented computer results.

The danger of a monodimensional uncompromising approach to the evaluation of phenomena of so called t-men (i. e. persons, using as the ultimate criterion the t-test) is unfortunately being replaced by the probable emergence of more complicated interpretational artifacts due to the schematic application of multidimensional computer methods. Often these cannot be even recognized. The reason is mostly in unsatisfying conditions of their application, primarily because of co-linearity and inaccuracy of variables. Limitations pertain not only to standard procedures of multiple regression but also to the method which has been devised to eliminate similar errors, i. e. factor analysis. At the use of this procedure which is justly regarded as one of the basic tools for the analysis of complex systems, there may be substantial mutual differences between the calculation of factors obtained by means of different methods and the interpretation of results is often controversial and illogical.

A frequent cause of errors is the use of inadequate models of phenomena. In some cases it is better to use nonparametric considerations and comparisons which are less sensitive but of greater generality. An example of a generally used model with only partial validity of

prediction of medium effects is the log-normal model which is characterized by high sensitivity for extrapolation. Estimates of the probable biological effect or risk differ in the area of ecologically important low doses even by several orders of magnitude. A more suitable procedure is binit dependence, described by us, which has no exponential character (DOLEŽAL, 1985). The issue is dependence between dose D_i and probability of effect p_i at its application expressed by two parameters K (slope of dependence) and $ED\ 50$ (medium effective dose) expressed by the formula

$$\sqrt{\frac{p_i}{1 - p_i}} - \sqrt{\frac{1 - p_1}{p_1}} = K \left(\sqrt{\frac{D_i}{ED\ 50}} - \sqrt{\frac{ED\ 50}{D_i}} \right)$$

The basic domain of the use of regression models is the prediction of values of dependent variable on the basis of knowledge of the values of variables regarded as independent. Application of results of regression analysis for the estimate of the structure and causal relationship between variables must, however, be considered mostly as inadequate and may produce serious interpretational artifacts. As an example may serve the attempt to interpret the cause of morbidity in a Prague district which was done with data about the age and density of the population, fly-ash fall out, concentration of lead, of nitrogen, sulphur oxides and carbon monoxide in view. In the correlation matrix all the coefficients between variables and indicators of morbidity were positive. An increase in the concentration of toxic agents logically led to an increase in morbidity. The normal procedure of multiple regression showed, however, that in the correlation between morbidity and population density and in the concentration of nitrogen oxides the signs of both partial correlation coefficients were inverted. The calculation would have indicated that greater population density and higher concentration of nitrogen oxides reduces morbidity. An interpretation could have been based on the notion of a smaller access to medical care in less populated areas and on the present antagonistic interaction of oxides with other noxious agents in the environment. The result could not, however, lead to the recommendation to increase automobile traffic in the hazard areas in Prague for the purpose of reducing morbidity, but, on the contrary, it demonstrated the inadequateness of the method used which produced this artifact. But, who can guarantee that in less clear situations even an experienced worker, on the basis of a similar statistically significant pseudoresult, will not draw the wrong conclusion and recommendation?

At whatever use of the computer, for assessment of complex phenomena an uncompromising demand must be not only the perfect knowledge of the method applied but also a logical verification of the results obtained. An abstract empirical approach of multidimensional statistics generates, for example, a greater risk of inadequacy and disregard of the degrees of freedom of the phenomenon studied. The number of studied objects should be at least 3x to 5x greater than the number of the monitored variables. In ancient Greece philosophers were called as "hoi sophoi", wise, who changed the unclear into clear, and "hoi sophistai", who, on the contrary changed the clear into unclear. Unfortunately there are not only workers but also computer programs that are in the nature of the latter category.

Abstract numerical expression of results based on computation of parameters is, true enough, standard and economical but for most of the time it does not permit to recognize at a first

approach deviations from linearity or deviating values even in the most simple correlations which in the classic graphic calculations showed up at first glance. One way for solving this problem could be a parallel numerical and graphic computer output of results. There exist a number of classical graphic procedures that could be suitably modified or restored for this purpose.

The modern statistical arsenal of biological sciences should also include even less accurate methods which on the other hand are less sensitive to random influences. Such procedures can determine the logical basis of results and verify or generate hypotheses about the structure and causal relations of the system studied. These problems are generally dealt with by TUKEY (1977).

Graphic methods that can limit errors in interpretation are as a rule of a very elementary nature and do not require particular erudition in statistics. They are, so to speak, visualised numericals. The use of at least two groups of methods should not be omitted in ecology.

First of all, it is the so called "path analysis" of Sewall WRIGHT (1918, 1960), devised already in 1918 which has hitherto only slowly entered into some scientific disciplines. In contrast to the symmetrical concept of correlation between variables in regression analysis it attempts to express causal relations. A simple numerical procedure forms a directed graph in which the symbols of variables are connected by means of arrows expressing their causal relationship. This method receives great attention in a monograph on the use of causal models in social sciences (BLALOCK, 1971). A very illustrative introduction to the method is the book by HEIS (1975) which was published also in a Russian translation.

The second approach is based on the method of dendrograms. So called "correlation pleiads" were described by TEREŇJEV (1928, 1960). The principle of the method is to form in this case a nondirected graph which connects elements of the correlation matrix whose correlation coefficient surpasses the chosen value (level of significance). Circles expressing variables are connected by lines of mutual relations. The universality of the method limits the necessity of choice of criteria values which may either be responsible for the design of a complicated and hard-to-interpret graph or, on the contrary, for the isolation of little-significant variables. A virtually same procedure was achieved independently by the American palaeontologist OLSON (1958). The use of the method of correlation pleiads in toxicology was described by LJUBLINA et al. (1963).

The construction of other types of dendrograms for taxonomic purposes which meets the requirement of a minimum sum of correlation coefficients was described by the Polish anthropologist PERKAL in 1951 and likewise by PRIM (1957). The method of dendrograms is dealt with in the now already classical monograph of SOKAL et SNEATH (1963) from the aspect of taxonomy. The scope of application in a number of areas is contained in the review edited by FELSENSTEIN (1983).

In conclusion I take the liberty of demonstrating for the needs of ecology a method perfecting on the procedure of correlation pleiads, which 15 years ago we applied successfully to the analysis of the structure of a neurotic symptoms questionnaire (DOLEŽAL, HAUSNER, 1973). The procedure was called "maximal correlation levels method" (MCLM) and in our experience possesses a greater degree of generality and information than the method of correlation pleiads.

The principle of MCLM is simple. For each symbol of the row the symbol of the column is selected with which it has the highest value of the correlation coefficient. The symbols are

entered in circles and in the direction from the row symbol an arrow leads to the column symbol. If there are several identical maximum values the symbol is chosen which, after completion of the operation, has most coordinated that is according to the principle of the simplest structure.

Maximum values are selected regardless of the sign. At each connecting line we express the numerical value and sign of correlation. The use of correlation coefficients is not obligatory, any other suitable measure of similarity can be used.

In the process as a rule several graphs depicting clusters are separated (at least one) the centre of which is formed by pairs of variables which mutually correlate highest in the set. These pairs are connected by two opposite directional arrows. By separating these double linkages or by the isolation of possible chains which could form further variables, it is possible to isolate subclusters of lower orders and analyse the character of their dependence. Separated clusters can again be mutually connected (by dashed lines) on the basis of the principle of maximum correlation. Computer verification effected in some cases yielded practically identical results. Analogically a graph of second level dependence can be constructed by connecting second level values for further interpretation.

Fig. 1. exemplifies graphic analysis by the MCLM of the relations of 16 variables found (among others) in *Microtus arvalis* caught in different localities in Bohemia (N = 217). Correlation coefficients were computed on a HP 85 computer along with factor analysis.

With the MCLM 3 clusters were separated. The first can be denoted as somatic. In this the central position is occupied by body weight (WB), weight of the liver (WL), followed by weight of the spleen (WS) and kidney (WK) and by length of the ear (LE) hind foot (LF) and tail (LT). Thus a subcluster WB - WS - HK was formed.

The second cluster is formed by blood proteins with the amount of albumin (ALB) and alpha-2-globulin (a₂G) in the central position. with a subcluster of total protein (TP) and gama globulin (γ G).

The third cluster is formed by the isolated pair of acetylcholinesterase (ACHE) and pseudo-cholinesterase (PCHE).

It is obvious that maximum information in the matrix is provided by WB and WL, ACHE, PCHE and ALB.

In comparison with this procedure factor analysis was performed in an identical matrix, using the method of maximum likelihood according to LAWLEY (1940), with a standard iteration program. The 4 factors obtained detected 55 % of total variance.

The first factor is most saturated in WB (0.54), WL (0.41), WR (0.30) and ALB (-0.48). The second in LF (0.14) and β G (-0.13). The third in a₂G (0.57), γ G

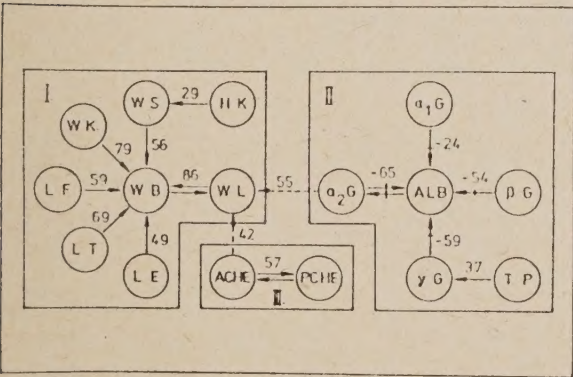


Fig. 1. Graphic analysis of the relation of 16 variables

(-0.51), TP (-0.23) and LE (-0.12). The fourth factor in ACHE (0.58), PCHE (0.53), WS (-0.26), LT (0.23), a₁G (0.21) and HK (0.15).

The ways (including rotation of factor) and means of interpretation of such factors obtained by a method regarded as standard and valid I leave to the daring reader only.

Graphic procedures need not necessarily yield staggering findings but they do at least guarantee the principle of logic of relations in complex systems, which we can use for the further validisation of results.

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Lognormal distributions - a theoretical model for biomonitoring

R. CH. ZIEGELBECKER

INTRODUCTION

In epidemiological studies in the fields of biology, medicine, etc., we often have numerous influences of varying importance that affect a measurable quantity we are interested in. Very often it is too expensive or even not possible to measure and control all of these influences.

If we are interested in eventual correlations between only two such quantities, it is sometimes sufficient to consider all of the other influences to be randomly distributed. It then is necessary

- to collect the data in a random and representative way,
- to check if they are sufficiently random, using an adequate scale ("elementary error scale", e. g. probits, logits, ..., as described in this paper), and
- to do (linear) regression analysis using this scale as an "invariant measure" of this quantity.

There are enough papers where a) is ignored (obviously leading to unusable results), or also where c) is not done, with the consequence of masking the true correlations. This is illustrated by Fig. 1 and Fig. 2. There the dashed lines indicate the conclusions of the authors of those diagrams, while the full lines give the conclusions as they would be drawn from a well suited net of coordinates as done later in this paper.

The mentioned adequate nets of coordinates are often based on lognormal distributions. Experimentally, we find such distributions e. g., confined on two sides, for dental caries (Fig. 3) and dental fluorosis (Fig. 7), and confined only on the lower bound, for the radioactivity in Austrian apples after "Tschernobyl" (Fig. 4).

In this paper, besides presenting further diagrams of this type and the conclusions to be drawn from them, we wish to explain that in many cases we do not have to search for the most suited scale which linearizes the problem (i. e. transforms the actual distribution to a normal one), but can predict it.

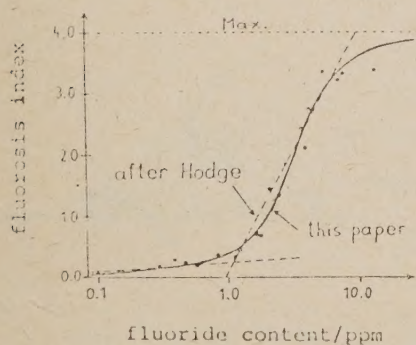


Fig. 1. Dental fluorosis index against logarithm of fluoride content in drinking water (after [1]).

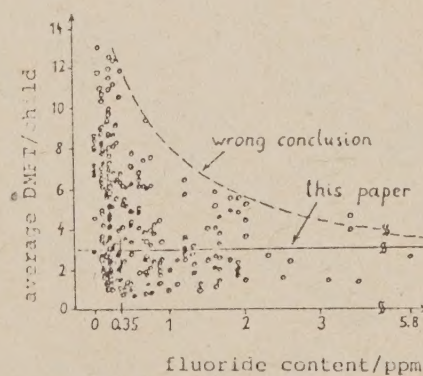


Fig. 2. DMFT (number of decayed, missing and filled teeth / child) against fluoride content in drinking water (after [2, 3]).

Let us assume that ε is the linear (ized) measure of a quantity x . Then the random fluctuation $\Delta\varepsilon$ means "a bit more" or "a bit less" of this quantity, e. g. brust more/less teeth, have better/worse nutrition, or have more/less sun or water (plants!), and is an equal probable step in either direction, with no regard to the actual size of the quantity. By means of the Galton board ([7], Fig. 5) it can be seen that under such conditions there follows a binomial distribution for ε , which in the limit of an infinite number of decision steps converges towards a normal distribution:

$$\varphi(\varepsilon) = \frac{1}{\sqrt{2\pi}} e^{-\frac{\varepsilon^2}{2}}$$

$$\Phi(\varepsilon) = \int_{-\infty}^{\varepsilon} \varphi(\varepsilon') d\varepsilon'$$

If there are no exceptional mechanisms in the special case, the relation between the physical "step size" Δx of the quantity x and the corresponding step $\Delta\varepsilon$ in its "invariant measure" depends only on the natural (a priori) bounds of x :

- 1) For $-\infty < x < \infty$ (typically: "small" errors) no range for x stands out, and therefore $\Delta\varepsilon \sim \Delta x$ (direct proportionality).
- 2) For $0 < x < \infty$ (typically: size, volume, weight of natural objects) for any actual value of x (e. g. size of plants) the same relative change can a priori be expected (e. g. caused by giving more water to these plants): $\Delta\varepsilon \sim \frac{\Delta x}{x}$.
- 3) For $0 < x < 1$... normalized upper bound (typically: percentages, concentrations, limited objects) neither bound is privileged. Therefore an "elementary error" $\Delta\varepsilon$ is equal to a change Δx in x which is relative to both bounds: $\Delta\varepsilon \sim \frac{\Delta x}{x(1-x)}$.

The transformation $\varepsilon(x)$ is now obtained by a simple integration, and the distribution density $\varphi(x)$ can be obtained by inserting this transformation into the normalizing equation $\varphi(\varepsilon)d\varepsilon = \varphi(x)dx$.

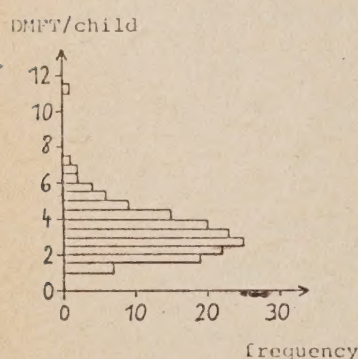


Fig. 3. (Confined lognormal) distribution of DMFT dental caries index per child in sites with less than 5000 inhabitants in 6 states of the USA (after [4]).

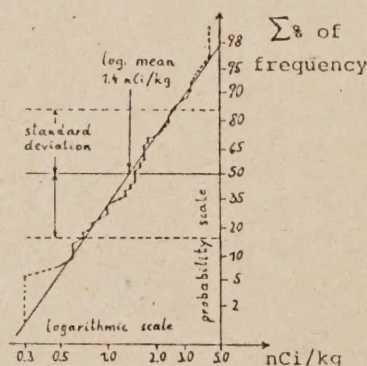


Fig. 4. (Lognormal) cumulative distribution function of radioactivity (Cs 137) in Austrian (Styrian) apples in summer 1986 [5, 6].

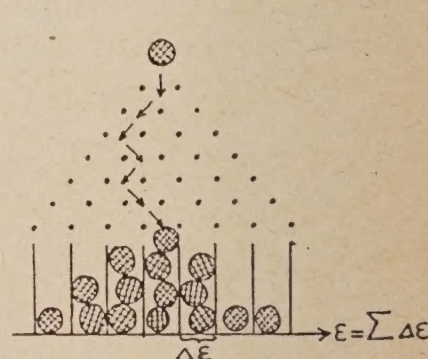


Fig. 5. Galton board.

The transformations corresponding to the above three cases are:

- 1) $\mathcal{E} = ax + b$
- 2) $\mathcal{E} = a \cdot \ln x + b$
- 3) $\mathcal{E} = a \cdot \ln \frac{x}{1-x} + b \quad (= a \cdot \text{logit } x + b)$

The corresponding types of distribution functions are sketched in Fig. 6.

TESTING OF THE DISTRIBUTION FUNCTION

In order to test if a special distribution function holds well for an actual set of measurements, we must arrange these measurements according to their size, then for every measured value x_i calculate the percentage Φ_i of measurements whose size is smaller or equal than x_i (= sum frequency distribution) and find the corresponding value of the argument $\mathcal{E}_i = \mathcal{E}(\Phi_i)$ of the normal distribution function $\Phi(\mathcal{E})$ (= normal equivalent deviation (NED) = = probit - 5). These arguments are then drawn in a diagram against the theoretical $\mathcal{E}(x_i)$ obtained by the transformation. Examples are given in the Figs. 4, 7 and 8.

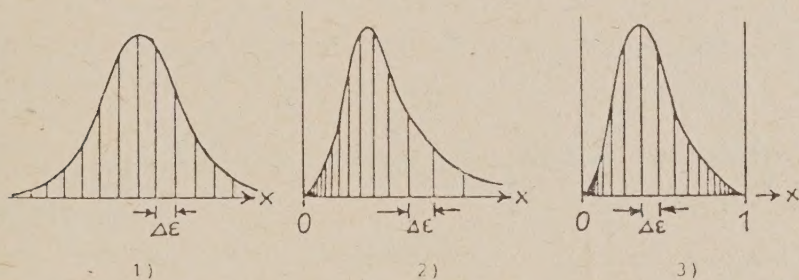


Fig. 6. Sketches of the distribution functions for the cases 1 - 3.

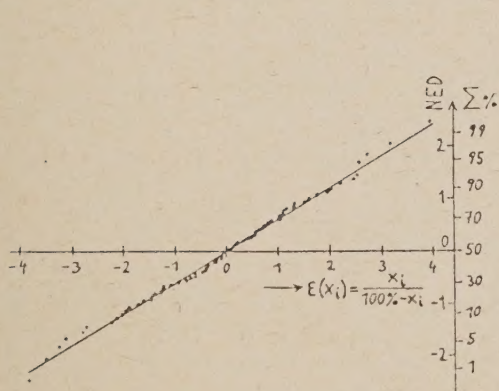


Fig. 7. The distribution of the percentages x of 9-14 years old children with dental fluorosis (67 sites USA, 6 sites DK, 1936 - 1965, [5, 9]) is a lognormal one, confined at 0 % and 100 %.

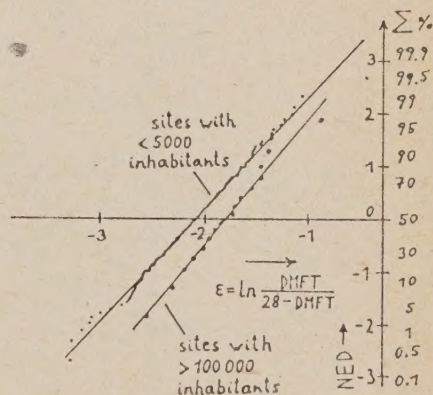


Fig. 8. Lognormal distributions of dental caries (DMFT) in 6 states of the USA, 1933/34 ([5, 8]); boundaries at 0 and 28 DMFT.

Since the total number of elementary errors contained in a special value ε (which in nature leads to a certain value of x) is something like an "invariant measure" of the quantity x , the most probable relation between two quantities x_1 and x_2 is given by the following thesis:

$\Delta \varepsilon_2$ of quantity is proportional to $\Delta \varepsilon_1$ of a cause.

This certainly holds in a model of multiplicative action of influences and allows linear regression analysis. Fig. 9 shows a sketch how a distribution (1) of DMFT indices would be shifted towards less DMFT values (2) by an influence such as "better" quality of nutrition, a) in the physical scale (28 DMFT = max.), and b) in the transformed ("elementary error") scale. In b) there occurs a shift of a normal distribution by a constant amount. (Therefore we call ε the "invariant measure" of x).

Deviations would indicate a departure from the multiplicative model. They would probably indicate influences which are connected to a certain absolute size of the quantity investigated, perhaps an additional boundary.

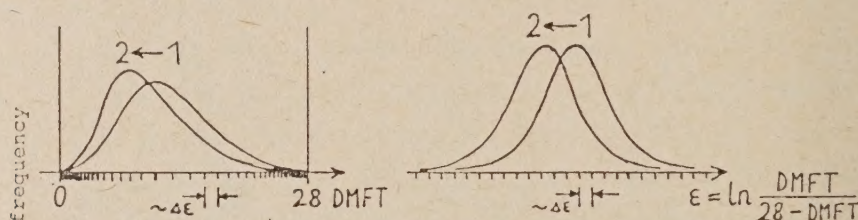


Fig. 9. Shift of a distribution caused by some influence, a) in the physical, b) in the "elementary error" scale.

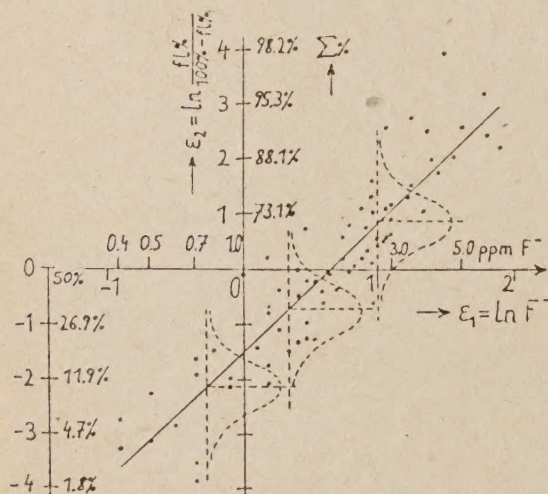


Fig. 10. Dependence of dental fluorosis on the content of fluoride in drinking waters. The regression is linear in the ε - scales. (fl % = percentage of children with dental fluorosis).

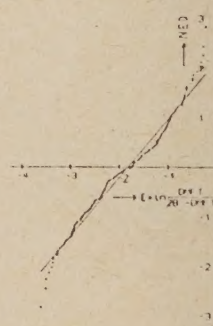


Fig. 11. The distribution of dental caries according to data taken from 25 fluoridation studies, 12-14 years old children, 1942-1970.

Since the concentration of a few ppm fluoride F^- in drinking water is negligibly small compared to 100 %, its "invariant measure" (Fig. 6, case 3) simply reduces to the logarithm.

As can be seen from Fig. 10, the (normal) distribution of ε_2 for $\varepsilon_1 = \text{const.}$ is shifted linearly to higher values for increasing $\varepsilon_1 = \ln F^-$. Here, no dose seems to be completely harmless.

By calculating the regression coefficients and considering the transformations we would obtain a curve for the dependence of dental fluorosis on the fluoride concentration like in Fig. 1.

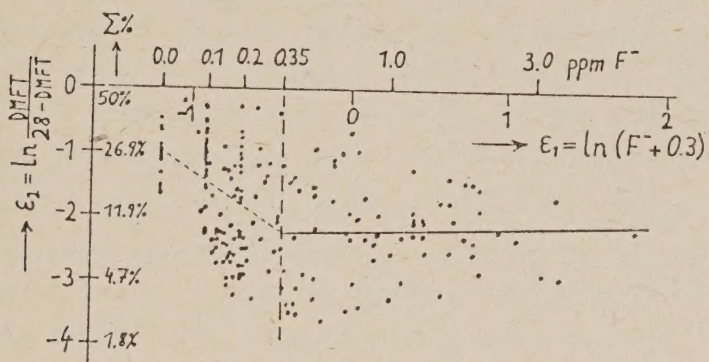


Fig. 12. Dental caries in relation to fluoride in drinking water. Data taken from 25 studies 1942-1970, children 12-14 years old.

Latest data from WHO:
(12 years old children)

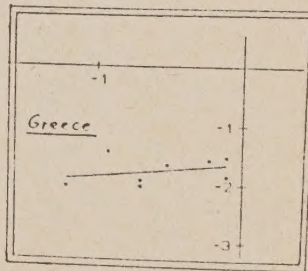
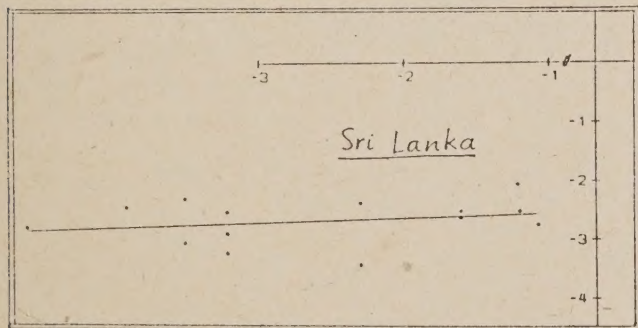
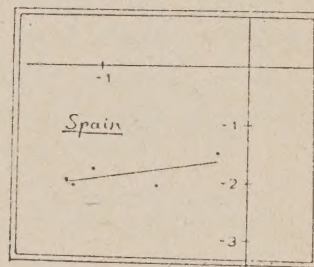
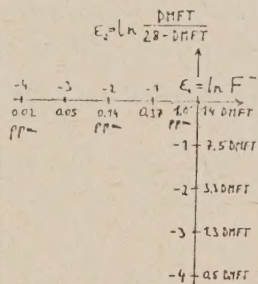
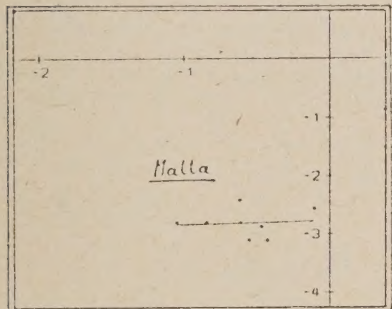


Fig. 13. Dental caries (DMFT) of children aged 12 plotted against the fluoride concentration (F^-) in drinking water using E^- scales (Data from WHO, 1987).

A test of the distribution of all dental caries data from fluoridation studies available to the author of [9] a few years ago gives hints on the existence of two groups of data therein (Fig. 11) which may be mainly due to data selections (see refs. [8, 9, 10]).

Indeed, a plot of all these dental caries (DMFT) against fluoride concentration (F^-) data using the $\mathcal{E}$ -scales introduced in this paper (adding 0.3 ppm F^- in order to get a realistic estimate of the total fluoride intake, and to be able to plot also the $F^- = 0.0$ ppm values) does not give a general negative slope of the regression (Fig. 12), which would be expected if fluoride in drinking water would generally reduce dental caries. In the contrary: The mutual dependence in this net of coordinates is neither linear, as expected in analogy to Fig. 10, nor is there a significant slope above a very small fluoride concentration (≈ 0.35 ppm). Nothing changes if $\mathcal{E} = \ln F^-$ is used. This was already found in ref. [9], where an approximation to the method described here was used. As mentioned above, the points at lower concentrations result at least partly from selections of data. However, the method is relatively insensitive against selections of data within the individual fluoridation studies.

In order to check whether the hypothesis of a general null effect of fluoride can be hardened or not (since the data points in Fig. 12 cannot be considered fully random and representative) we travelled to Geneva where we could get the latest WHO data on DMFT and fluoride concentration values all over the world [11] which we consider to be sufficiently random, and representative for the country within the framework of the WHO investigations.

We then took the countries in which we found a wider range of fluoride concentrations in drinking water, and within these countries, the cities or locations where we could find DMFT values also. Using the $\mathcal{E}$ -scales (with $\mathcal{E} = \ln F^-$), we got the surprising Fig. 13.

In Fig. 13, all data investigated are shown, no data were excluded. No reduction of dental caries by fluoride can be seen, the opposite is even possible.

Fig. 14 shows the diagrams that would result if all 35 data points are put together, but they should not be overrated since they only contain one asiatic and three european countries.

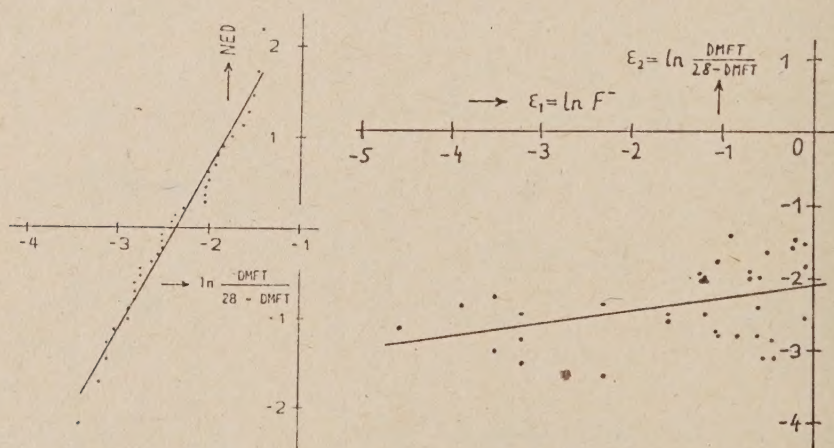


Fig. 14. Check if the entity of WHO DMFT values of 12 years old children is lognormal confined on both sides (left) and a plot of these values against the fluoride concentrations in drinking water using $\mathcal{E}$ -scales (right).

C O N C L U S I O N

The method discussed in this paper seems to be an adequate tool for investigating mutual dependencies of two physical quantities characterized by statistical distributions over wide ranges. Latest applications of this method suggest an overall null effect of fluoride in drinking water on the dental health of 12 years old children.

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Ruderal plants as bioindicators in the industrial areas of Westberlin

F. REBELE

One of the most significant components of air pollution in Westberlin is sulphur dioxide. Therefore the pollution type of the entire area of Westberlin can be characterized as SO_2 -type. SO_2 is being continuously measured since 1975 and average annual means of about 0.15 mg/m^3 in the inner city areas and some 0.08 mg/m^3 in the outer regions (Senator für Stadtentwicklung und Umweltschutz 1984). Monitoring stations are chiefly implemented in the settlement areas and the surroundings but not in the industrial regions.

In the industrial areas besides sulphur dioxide a lot of different pollutants are emitted from numerous industrial sources, fossil-fueled power plants, incinerating plants, and home firing. Therefore, the pollution type of the industrial areas in Westberlin is very complex. Data of emitted pollutants, their distribution and concentration in the ambient air are rarely available. Nevertheless, one can assume that various airborne harmful substances are deposited on soil and vegetation and are contaminating urban ecosystems.

Besides air pollution and deposition of airborne pollutants direct deposition of toxic substances and contamination of soil and groundwater is a great problem. More than 150 hazardous depositions (so-called "Altlasten") have been detected within the last years, including chemical substances like benzol, phenol, toluol, PCB, dioxin, beryllium, arsenic and various heavy metals (HUTTARD, HABERKORN, 1985; Tagesspiegel 29.5.1985, Tagesspiegel 30.4.1988).

In spite of numerous depositions, vegetation in the industrial areas of Westberlin, in general, is low affected by pollutants. In an international scale there are medium loads of pollution and visible injuries of wildliving plants can rarely be observed. The main reason is that natural vegetation of the industrial areas is chiefly ruderal vegetation, which has developed on man-made habitats. Most of the ruderal plants of urban-industrial sites are more or less resistant against pollutants.

With the exception of extremely herbicide treated areas or directly contaminated areas by industrial wastes, pollution is only an additional but not a determining or limiting factor for plant growth on ruderal sites. For example, investigations carried out by MEYER (1986) showed that application of cadmium, PCP and ozon had only low effect on growth of Solidago canadensis. Field experiments on Cd polluted soil (using much higher concentration of Cadmium than it was found in ruderal soils in Westberlin by BLUME et HELLRIEGEL, 1981) showed no significant influence on species composition of ruderal vegetation on sandy soil, but abundance of dominant Solidago canadensis was greater (CORNELIUS, 1985).

Floral surveys of numerous industrial areas in Westberlin showed that factory ground and especially industrial fallow land can be of high species richness (REBELE, 1988). About 600 vascular plant species are growing in the industrial regions, including species recorded to be sensitive to fluorine pollution like Arrhenatherum elatius, Dactylis glomerata, Hypericum perforatum or Convallaria majalis (BORSCH, 1960; BOLAY, BOVAY, 1965).

In the industrial areas of Westberlin we cannot find industrial climax communities sensu WOLAK (1980), because there are no great point sources like iron-, zinc- or copper smelters or fertilizer plants etc. causing extremely high contamination of soil and vegetation by air pollution.

Nevertheless or even, urban-industrial ecosystems in Westberlin are contaminated with a lot of pollutants. Also resistant plants can be effected and show invisible injuries, for instance, reduced photosynthesis and, in consequence, reduced biomass production. Toxic pollutants can be enriched in the food chain and distributed in the environment.

Plants can take up pollutants by their roots from polluted soil or directly by their leaves. The kind of uptake, translocation, collection and retention of pollutants is very specific and depends on morphology, anatomy and physiology of the plant species or genotype.

Resistant plants, which are accumulating pollutants are, in general, called accumulating bio-indicators. Following the thesis of KNABE (1982), that dominant or key species of an ecosystem are the best indicators of environmental quality for a given site, in urban ecosystems and chiefly in industrial areas you have to analyse ruderal vegetation, because this is the dominant vegetation type.

BORTITZ et DMSLER (1980) have already pointed out that ruderal plants like Sambucus nigra, Tanacetum vulgare, Urtica dioica or Artemisia vulgaris can be suitable bioindicators.

In the industrial areas of Westberlin ruderal plants like Solidago canadensis, Artemisia vulgaris and Calamagrostis epigeios are growing everywhere and are dominant species in plant communities. One of the most frequent tree in our industrial areas is Robinia pseudacacia. Plantago major as a characteristic species of trampling sites can also be found nearly everywhere.

Some experience was already gained with Artemisia vulgaris (ATRI, BORNKAMM, 1984), Solidago canadensis (FAENSEN et al., 1977) and Plantago major (GLOE, 1979) indicating the effect of cadmium or lead pollution in urban habitats, especially near roadsides. Calamagrostis epigeios was recorded to accumulate lead, especially in seeds (SAROSIEK, 1959). Robinia pseudacacia was also used for monitoring pollutants by some investigations in urban-industrial areas (KALETA, 1978; KOVACS et al., 1982).

In an own investigation in 1982 leaf samples of the above mentioned five widespread ruderal plants were collected in 11 industrial areas in Westberlin on factory ground or industrial fallow land and a control site in the Grunewald Forest. Foliage samples of Artemisia vulgaris, Calamagrostis epigeios, and Solidago canadensis were collected from an area of about 1 to 4 m², where they were growing together on the same site (Tanaceto-Artemisietum rich in Solidago canadensis and Calamagrostis epigeios). Leaf samples of Robinia pseudocacia and Plantago major were collected from the next locality nearby within the same plot. Figure 1 shows an example of a sampling area in an industrial region in the south of Westberlin.

Sampling date was end of August - beginning of September. Coarse particles were washed off with tap water, plant material was dried at 105° C and analyzed after pulverization for cadmium, lead, copper, zinc, fluoride and sulphur. Digestion for heavy metal analysis was done with nitric acid in pressure bombs, analysis by means of atomic absorption spectrometry (Perkin Elmer). Fluoride was determined by means of an ion-sensitive electrode (Orion) after ashing

Tab. 1. Range of heavy metal, fluoride and sulphur content of leaves (means in ppm d. m.) from 11 industrial sites and a control site (figures in parenthesis) in Westberlin. Data from REBELE (1986).

	Cd	Pb	Cu	Zn	F	S
<i>Artemisia vulgaris</i>	0.34-2.57 (0.88)	4.3-31.1 (2.2)	16-172 (20)	87-164 (116)	7-49 (14)	2190-6000 (2560)
<i>Solidago canadensis</i>	0.03-0.78 (0.12)	2.8-37.9 (2.7)	6-160 (8)	38-103 (35)	9-69 (9)	1450-4890 (2340)
<i>Calamagrostis epigeios</i>	0.04-0.36 (0.11)	0.6-6.0 (1.8)	3-29 (6)	27-135 (36)	3-12 (4)	1730-3440 (2640)
<i>Robinia pseudacacia</i>	0.01-0.46 (0.07)	2.3-18.6 (1.0)	3-68 (5)	24-99 (32)	6-40 (7)	2120-7320 (3880)
<i>Plantago major</i>	0.35-1.16 (0.31)	2.6-25.0 (0.9)	9-152 (11)	69-225 (56)	4-15 (6)	9630-22940 (17130)

and alcalic digestion with NaOH (following REUSMANN et WESTPHALEN, 1969). Total sulphur content was analysed using the method of SCHWAGER et KELLER (1976).

Tab. 1. shows the range of means of element content in the leaves of the five ruderal plants. The 6 analyzed pollutants have been accumulated by the five plants in a very different extend. For example, cadmium concentration in leaves of *Artemisia vulgaris* is on average ten times higher than in leaves of *Robinia pseudacacia*, seven times higher than in leaves of *Calamagrostis epigeios*, about five times higher than in leaves of *Solidago canadensis* and nearly twice as much than in leaves of *Plantago major*.

Artemisia vulgaris also showed the highest levels of copper, wheras in leaves of *Solidago canadensis* the highest amounts of lead and fluoride could be analyzed. *Plantago major* was the best zinc and especially sulphur accumulator. The highest foliar sulphur levels of *Plantago major* averaged 2.3 % in dry matter.

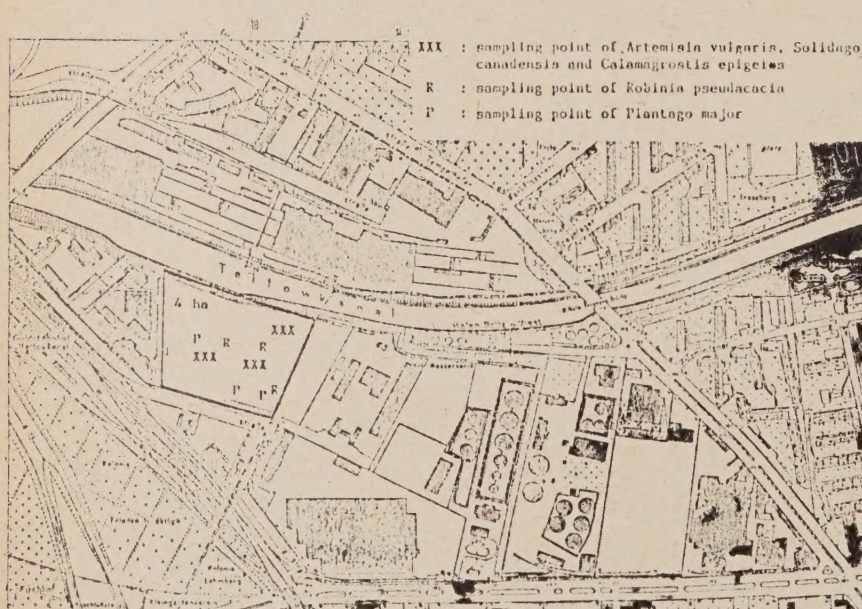


Fig. 1. Example of sampling area (IX): industrial fallow land in the Tempelhof/Neukölln industrial region in the south of Westberlin.

Tab. 2. Cd- concentration in different organs of Artemisia vulgaris and Calamagrostis epigeios collected from the same sampling site (standard deviation in parenthesis; n = 3).
Localities (corresponding sampling areas in figure 2a - 2f):
I. Dahlemer Feld, Grunewald Forest, Jagen 90;
V. Motardstr., Spree industrial region, Berlin-Spandau (industrial fallow land)
VII. Montanstr., industrial region Berlin-Wilhelmsruh (industrial fallow land).
Sampling date: September 1984. Data from REBELE (1986).

site	I	V	VII
<u>Artemisia vulgaris</u>			
root	0.26 (0.09)	0.61 (0.33)	1.08 (0.38)
rhizom	0.30 (0.03)	0.75 (0.30)	0.77 (0.02)
stem (1 st)	0.52 (0.05)	0.97 (0.34)	0.70 (0.15)
stem (2 nd)	0.56 (0.11)	0.93 (0.40)	1.23 (0.16)
leaves (1 st)	0.63 (0.18)	1.15 (0.33)	1.78 (0.06)
leaves (2 nd)	0.60 (0.17)	1.26 (0.28)	1.67 (0.43)
flowers	0.40 (0.09)	0.81 (0.31)	1.12 (0.23)
<u>Calamagrostis epigeios</u>			
root	0.96 (0.41)	3.93 (0.97)	10.44 (2.86)
rhizom	0.20 (0.11)	0.83 (0.38)	0.99 (0.14)
culm	0.02 (0.01)	0.21 (0.25)	0.04 (0.04)
leaves	0.01 (0.00)	0.21 (0.09)	0.20 (0.08)
flowers	0.16 (0.02)	0.57 (0.16)	0.43 (0.10)
litter	0.11 (0.05)	1.06 (0.06)	1.23 (0.61)

Another investigation in 1984 showed that distribution of heavy metals in above and below ground organs of Artemisia vulgaris and Calamagrostis epigeios is very different. Table 2 shows an example for cadmium accumulation in plants growing on a low contaminated site and two high contaminated industrial sites. Calamagrostis epigeios accumulates most of the heavy metal cadmium in the roots, whereas Cd content in leaves is very low. In contrary Artemisia vulgaris accumulates Cd mainly in the leaves. For other investigated heavy metals (lead, zinc and copper) similar results were obtained (REBELE, 1986).

Concerning Solidago canadensis MEYER (1986) showed that after Cd-contamination of substratum, Cd-content is highest in roots of Solidago canadensis also. GLOE (1979) measured Cd in roots and foliage of Plantago major collected from different sites in Westberlin and found higher concentrations in leaves than in roots.

If we compare the content of the five investigated ruderal plant species collected from 11 industrial sites and a control site in an open field in the Grunewald, we found high correlation of copper and fluoride contents (Tab. 3). In most cases correlation is also given for lead-, cadmium- and sulfur contents. Regarding foliar zinc levels, correlation was only significant for Robinia pseudacacia and Solidago canadensis and Robinia pseudacacia and Calamagrostis epigeios, respectively.

This shows that, with the exception of zinc, accumulating dominant ruderal plants are representative for the vegetation of these sites. Comparing sampling sites we found most significant differences for the best accumulating plants, in general. An example is given

Tab. 3. Correlation of Cd-, Pb-, Cu-, Zn-, F- and S- leaf contents of five ruderal plant species; significant values are underlined; $p < 0.05$

r	<i>Artemisia vulgaris</i>	<i>Solidago canadensis</i>	<i>Calamagr. epigeios</i>	<i>Robinia pseudac.</i>	<i>Artemisia vulgaris</i>	<i>Solidago canadensis</i>	<i>Calamagr. epigeios</i>	<i>Robinia pseudac.</i>
Plantago major	<u>0.67</u>	<u>0.63</u>	0.51	<u>0.69</u>	<u>0.85</u>	<u>0.86</u>	<u>0.73</u>	0.50
Robinia pseudac.	<u>0.86</u>	<u>0.95</u>	0.52		<u>0.72</u>	<u>0.70</u>	<u>0.65</u>	
Calamagr. epigeios	0.35	<u>0.61</u>			<u>0.90</u>	<u>0.93</u>		
Solidago canadensis	<u>0.82</u>			Cd	<u>0.99</u>			Pb
Plantago major	<u>0.99</u>	<u>0.96</u>	<u>0.96</u>	<u>0.99</u>	0.38	0.55	0.20	0.45
Robinia pseudac.	<u>0.99</u>	<u>0.96</u>	<u>0.95</u>		-0.12	<u>0.71</u>	<u>0.70</u>	
Calamagr. epigeios	<u>0.96</u>	<u>0.94</u>			-0.33	0.35		
Solidago canadensis	<u>0.98</u>			Cu	0.18			Zn
Plantago major	<u>0.60</u>	<u>0.66</u>	<u>0.77</u>	<u>0.80</u>	0.50	<u>0.57</u>	0.11	0.49
Robinia pseudac.	<u>0.93</u>	<u>0.96</u>	<u>0.90</u>		<u>0.68</u>	<u>0.71</u>	0.47	
Calamagr. epigeios	<u>0.90</u>	<u>0.90</u>			<u>0.63</u>	0.51		
Solidago canadensis	<u>0.97</u>			F	<u>0.66</u>			S

in Tabl. 4 for F- contents. We got the most significant differences for *Solidago canadensis*, followed by *Artemisia vulgaris* and *Robinia pseudacacia*. *Plantago major* and *Calamagrostis epigeios* are weak bioindicators in that case.

Corresponding to our results we can recommend those ruderal plants accumulating a certain pollutant in their leaves and which are representative for the vegetation type.

Artemisia vulgaris seems to be an universal bioindicator of urban-industrial ruderal sites. Leaves of *Artemisia vulgaris* are suitable to indicate heavy metal, especially cadmium and copper pollution. But fluorine and sulphur accumulation is also sufficiently high to show differences between higher and lower contaminated sites. Leaves of *Solidago canadensis* can be used for lead and fluorine pollution monitoring. *Plantago major* is a good indicator for sulphur. In lack of other suitable plants for biomonitoring, leaves of *Plantago major* can be also used for indicating heavy metal pollution. But problems may occur with secondary dust. Leaves of *Robinia pseudacacia* may be appropriate to indicate fluoride and sulphur dioxide better than heavy metal pollution.

Though *Calamagrostis epigeios* is one of the most resistant higher plants of our flora at all, leaves of *Calamagrostis epigeios* are not suitable for bioindication under conditions of medium pollution load. Using roots of *Calamagrostis epigeios* is promising but more uncomfortable.

Using ruderal plants as bioindicators in industrial areas the investigation carried out in 1982 showed that nearly all industrial sites were significantly high contaminated with at least one of the determined elements. Fig. 2 shows the content of Cd and Cu in leaves of *Artemisia vulgaris*, Pb and F in leaves of *Solidago canadensis*, Zn and S in leaves of *Plantago major*. Highest cadmium and copper accumulation was found in *Artemisia* plants growing 500 m NW of a copper recycling refinery. Highest lead concentrations were found in plants of an industrial area in the Spree industrial region with a lot of factories of electric industry, a power plant and

Tab. 4. Significant differences between F- contents of leaves from 11 industrial (II - XII) and a control (I) sampling site in Westberlin using Duncans multiple range test

Solidago canadensis													Artemisia vulgaris												
	IX V II X XII XI VII VIII VI IV I													IX V II X XII XI I VII VIII VI III											
III	+ + +												IV	+ + + +											
I	+ + +												III	+ + +											
IV	+ + +												VI	+ +											
VI	+ + +												VIII	+ +											
VIII	+ + +												VII	+ +											
VII	+ + +												I	+ +											
XI	+ +												XI	+ +											
XII	+ +												XII	+ +											
X	+ +												X	+ +											
II	+												II	+ +											
V	+												V	+											

Robinia pseudacacia													Plantago major												
	IX V VI X II VII VIII I IV XI XII													IX VI X V IV XI VIII VII I II XII											
III	+ +												III	+											
XII	+ +												XII	+											
XI	+ +												II	+											
IV	+ +												I	+											
I	+ +												VII	+											
III	+ +												VIII												
VII	+												XI												
II	+												IV												
X	+												V												
VI	+												X												
V	+												VI												

Calamagrostis epigeios												
	IX V X XI IV VI VIII VII XII II I											
III	+											
I												
II												
XII												
VII												
VIII												
VI												
IV												
XI												
X												
V												

+: significant difference; $p < 0.05$; $n = 3$
I - XII: localities corresponding Fig. 2

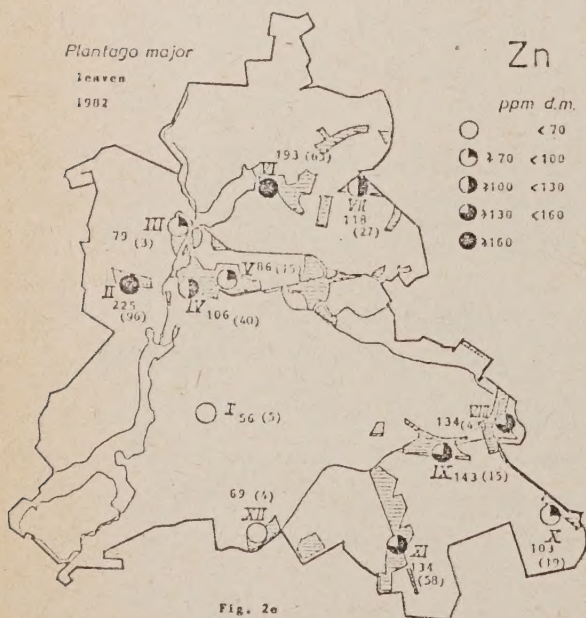
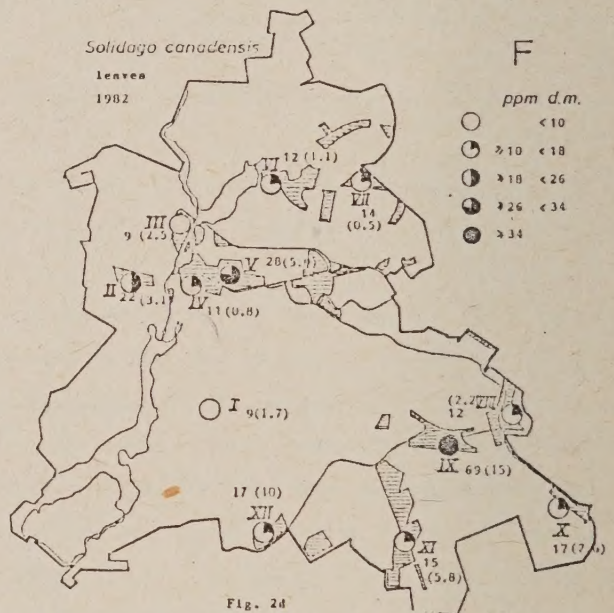
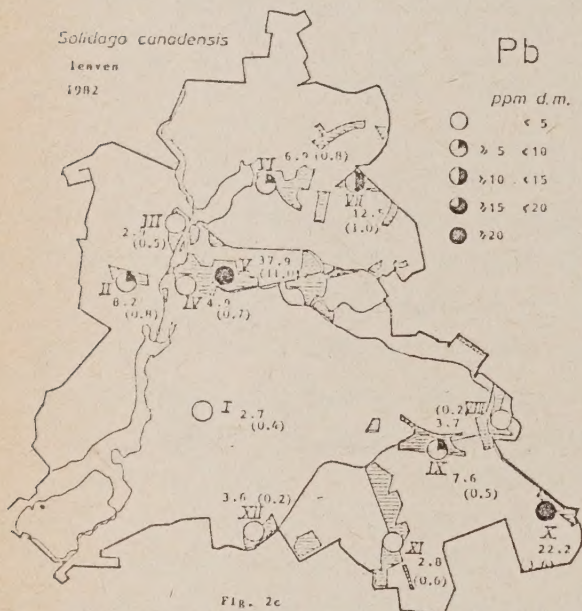
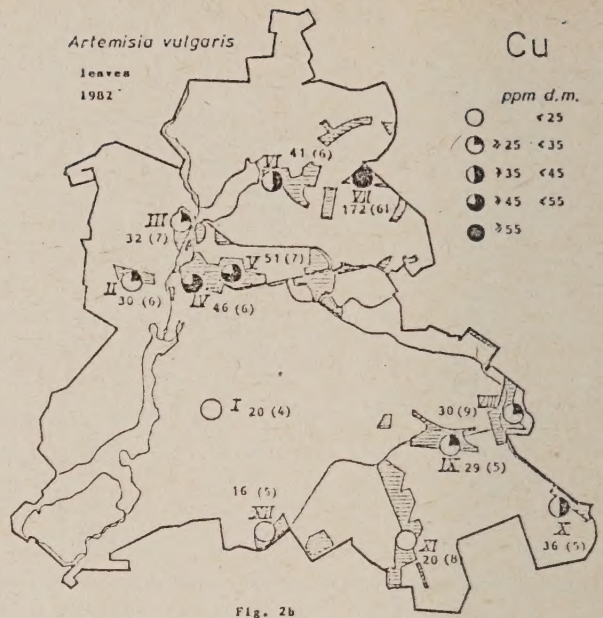




Fig. 3. Monitoring lead pollution in the vicinity of a lead accumulator factory by *Solidago canadensis* and *Robinia pseudacacia*.

Fig. 2a - 2f: Monitoring heavy metal (Cd, Pb, Cu, Zn), fluoride and sulphur pollution by means of ruderal bioindicators. Map of Westberlin to show main industrial regions. Means of leaf contents; $n = 3$; stand. dev. in parenthesis. Sampling date: 20.8. - 9.9.1982.

- I Dahlemer Feld, Grunewald, Jagen 90 (open field in the forest)
- II Orenstein & Koppel, Brunsbüttler Damm 144-208 (factory ground)
- III Rauchstr. 45-56 (industrial fallow land)
- IV Am Schlangengraben 18-20 (industrial fallow land)
- V Osram, Nonnendammallee 44-59 and Motardstr. (industr. fallow land)
- VI Borsigwerke, Berlinerstr. 27-37 (fallow land on factory ground)
- VII Montanstr. 18-28 (industrial fallow land)
- VIII Zwischen der Industriebahn, dem Unterhafen und der Grenzallee
- IX Saalburgstr. 4 (industrial fallow land)
- X Viessmann-Werk, Kanalstr. 13-41 and 10-26 (factory ground)
- XI Buckower Chaussee 114-125
- XII Fallow land south of the Steglitz-Zehlendorf industrial area

Sulphur content in all investigated plants was highest in leaves collected from an industrial area at the southern border of Westberlin in the immediate vicinity of an artificial fibre spinning factory. Sulphur levels in all investigated plants were elevated twice or three times as high than "normal" foliar sulphur levels.

In an international scale sulphur contamination of this site is evidently very high. FREDMAN et HUTCHINSON (1980), who investigated soil and vegetation in the vicinity of the world's greatest emitter of sulphur dioxide (the nickel and copper smelter at Sudbury in Ontario, Canada) found sulphur levels in leaves of Solidago canadensis up to 3600 ppm, whereas foliar sulphur concentration of Solidago canadensis samples collected on industrial site XII in Westberlin averaged 4890 ppm dm. It is remarkable that sulphur content is not correlated with 1982 summer half-year concentrations of SO₂ measured at the nearby SO₂ monitoring station (REBELE, 1986) and is also not correlated with long-term isolines of SO₂-concentrations in Westberlin. Therefore other (local) sources of sulphur contamination must be taken into account.

Above mentioned example shows that ruderal plants can be suitable to detect polluted areas in the industrial regions and to diagnose the relevant pollutants. However, some remarks are necessary. Comparing leaf contents of plants collected from industrial sites with those from the control site far from industrial areas, some elements are higher concentrated in leaves collected from the "control" than collected from some industrial sites. That concerns, especially, for sulphur and cadmium. This shows that in Westberlin, a really uncontaminated control site does not exist. Anyway, results shown in figure 2 must not be overinterpreted. Pollutant contents determined are only valid for the sampling areas and not for the whole industrial region. Within site variation can be high, even if sampling points are very narrow within the same sampling area. Therefore a denser sampling net is recommended to detect local sources and evaluate environmental pollution.

In another investigation in 1985 spatial distribution of lead in the vicinity of a lead accumulator factory in Westberlin was studied (table 5 and figure 3). Lead content in leaves of Solidago canadensis was highest in the direct vicinity of the factory and decreases with increasing distance from the pollution source. Lead contents exceeded maximum values from the former investigation in the main industrial regions of Westberlin. Mean foliar lead level of three neighbouring Robinia pseudacacia trees was about 30 times higher than lead content of Robinia leaves collected from a control site in the Grunewald Forest.

From other studies carried out in industrial areas in Westberlin, data for less widespread ruderal plants are given in table 6. Highest foliar fluoride levels averaged 96 ppm at the high F-contaminated site (IX) of the above mentioned study. Besides fluorine Sambucus nigra seems to be also a good accumulator for lead.

Above-ground shoots of Chelidonium majus accumulate best sulphur, lead and zinc. Poa annua showed high heavy metal and sulphur concentrations. In that case, the whole plant was collected and analysed for pollutants. Though accumulation can be high in plants like Sambucus nigra, Chelidonium majus or Poa annua, in our industrial and urban areas in Westberlin, ruderal plants like Artemisia vulgaris and Solidago canadensis are more suitable for biomonitoring because they are more frequent, more dominant and representative in our ruderal ecosystems.

Summarizing our findings we can say that widespread ruderal plants are suitable for biomonitoring in urban-industrial areas even under complex immission conditions and medium loads of pollution.

Tab. 5. Lead content in leaves of *Solidago canadensis* and *Robinia pseudacacia* collected in the vicinity of a lead accumulator factory (st. dev. in parenthesis; n = 3; sampling date: 10.9.1985; leaves unwashed; data from REBELE (1984).
Sampling sites I - XVII and 1, 2, 3 corresponding Fig. 3;
D. F. Danlemer Feld, Grunewald (control site).

Solidago canadensis			
site	Pb ppm d. m.	site	Pb ppm d. m.
I	12.5 (8.9)	X	19.2 (6.1)
II	50.9 (3.2)	XI	22.3 (4.3)
III	46.6 (3.1)	XII	10.1 (1.2)
IV	41.0 (4.9)	XIII	17.3 (4.9)
V	16.6 (1.7)	XIV	20.0 (2.2)
VI	21.1 (1.1)	XV	15.0 (3.4)
VII	50.6 (18.6)	XVI	10.8 (1.1)
VIII	28.7 (4.2)	XVII	5.4 (0.8)
IX	10.0 (0.4)	D.F.	3.3 (0.2)

Robinia pseudacacia			
site	Pb ppm d. m.	site	Pb ppm d. m.
1, 2, 3	83.3 (26.1)	D.F.	2.6 (0.2)

Tab. 6. Cd-, Pb-, Cu-, Zn-, F-, and S-contents of *Sambucus nigra*, *Chelidonium majus* and *Poa annua* collected from industrial sites and a control site (figures in parenthesis) in Westberlin; means in ppm d. m.

	Cd	Pb	Cu	Zn	F	S
<i>Sambucus nigra</i> (leaves)	0.14	38.2	10	-	32 - 96 (14)	-
<i>Chelidonium majus</i> (shoot)	0.17 - 1.50 (0.36)	5.8 - 82.3 (4.6)	7 - 58 (13)	67 - 1291 (80)	-	3830 - 7190 (4390)
<i>Poa annua</i> (whole plant)	0.78 - 6.72 (1.78)	6.5 - 180.8 (4.7)	22 - 228 (13)	128 - 1954 (89)	-	3840 - 9440 (7560)

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Pflanzen als Weiser der Verunreinigung des Regens in Warszawa

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Die Anwendung der Pflanzen zur Bioindikation der Umweltverunreinigungen in industriellen und urban Gebieten liefert wertvolle quantitative Informationen. In vielen Ländern prüft man die chemische Zusammensetzung und Reaktion der Niederschläge aller Art. Über den direkten Einfluss der Niederschlagswasser/verunreinigungen auf Pflanzenwachstum liegen nur wenige Daten vor. Es ist selbstverständlich, dass bei einer Luftverunreinigung die Niederschläge unabhängig von ihrem physikalischen Zustand den Boden zusätzlich mit den Schadstoffen anreichern und gleichzeitig seine Eigenschaften herabmindern. Eine Versäuerung des Niederschlagswassers kann also zu einer erhöhten Aufnahme der Schwermetalle z. B. Zn und Pb durch Wurzelsysteme führen.

MATERIAL UND METHODEN

Das Niederschlagswasser wurde von April bis Juli 1976 in sechs Stellen in Warszawa einerseits ausserhalb des Einflussbereichs des Strassenverkehrs, also in Parks, andererseits im Strassenbereich gesammelt.

Es wurden Bestimmungen vorgenommen wie folgt:

- chemische Zusammensetzung der Niederschlagswassers spektrofotometrisch - ASA - Spektrofotometer der Firma Perkin Elmer Mo. 300,
- Schwefel (SO_4) - nefelometrisch,
- Chlor - argentometrische,
- Reaktion - elektrometrisch.

Als Testpflanzen wurden Gemüsesorten mit der bekannten Empfindlichkeit gegenüber den meisten Schadstoffen der Grossstadtatmosphäre gewählt (SAX, 1974):

- Pekinense Kraut - Brassica oleracea var. capitata Pekinense L.,
- Freiland Rettichen - Raphanus sativus var. sativus L.,
- Rote Beete "Salisbury" - Beta vulgaris ssp. esculenta Salisbury L.,
- Grünerbse - Pisum sativum L.

Die Keimkraft der Samen wurde nach DORYWALSKI et al., (1964) bestimmt. Samen wurden auf das feuchte Filterpapier gelegt. Wasserpotential war gleich Null, (Temp. 24°C, rel. Luftfeuchtigkeit 75 % und Feuchtigkeit des Filterpapiers ca. 100 %).

Die Zucht erfolgte laut Hinweise von PALUCH (1966) und wurde nach Ausbildung von Kotylen und Erscheinung von Blattnorpen unterbrochen. Es wurde gezählt bzw. gemessen: Prozentsatz der gekeimten Samen, Länge des Wurzels und des Sprosses sowie das Verhältnis zwischen den beiden Längen. Man sprach ausserdem die Farbänderungen und Nekrosenbildung auf den Sämlingen an.

Zur Bewertung der Ergebnisse wurde Student-Test verwendet.

BONÁČ J., RŮŽIČKA V. (eds.), 1989: Proc. Vth Int. Conf. Bioindicators Deterioration of Regionis. Institute of Landscape Ecology CAS, České Budějovice, pp. 55-59.

E R G E B N I S S E

Im Niederschlagswasser in Warszawa wurden folgende Elemente in abnehmender Menge festgestellt: Ca, S/SO₄, Na, K, Cl, Mg, Mn, Zn, Pb (Tab. 1). Wobei Ca, S/SO₄, K, Cl und Na traten durchschnittlich in beinahe doppelter Menge in Strassenbereichen im Vergleich zu den Messpunkten in Parks.

Auch die Reaktion des Niederschlagswasser im Strassenbereich war entschieden sauer pH 3,7-4,0 und entsprechend höhere pH-Werte von 5,0 - 5,4 wurden in den Parks gemessen (Tab. 1).

Die Keimkraft der Samen war deutlich niedriger bei Niederschlagswasser von Strassenbereich im Vergleich zum Parkbereich:

für Pekinese Kraut um	10 - 20 %
Rettiche "	15 - 30 %
Rote Beete "	20 - 30 %
Erbse "	15 - 25 %

Das Wachstum der getesteten Sämlinge war signifikant niedriger ($P = 0,05$) unter Verwendung vom Wasser aus Strassenbereich als dem aus den Parks. In der ersten Entwicklungsphase beobachtete man allgemein ein schnelleres Wachstum der Sämlinge im Niederschlagswasser von Strassenbereich als in dem von Parkpunkten.

Diese Stimulierung wäre auf die Anreicherung von Mikroelemente im Strassenbereich zurückzuführen. Das "explosive" Wachstum wurde demnach schlagartig herabgesetzt, die Hauptwurzel wurden deutlich mazeriert und die Seitenwurzel wurden unterbildet wobei kamen intensiv die Schimmelfilze vor.

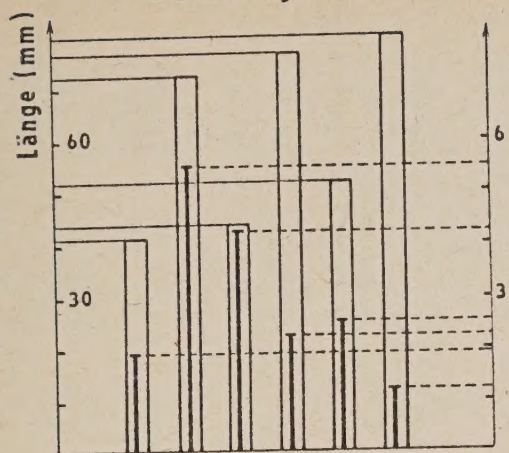
Visuell wurden einige Deformationen (Abb. 1) wie z. B. eine Verdickung und Verkürzung vom Hypokotyl (Rettich und Pekinese Kraut); Verkürzung des Hauptwurzels (alle untersuchten Pflanzen); Schwund oder Mazerierung des Hauptwurzels (Rettich und Erbse); Schwund der Seitenwurzel (Rote Beete).

D I S K U S I O N U N D S C H L U S S F O L G E R U N G E N

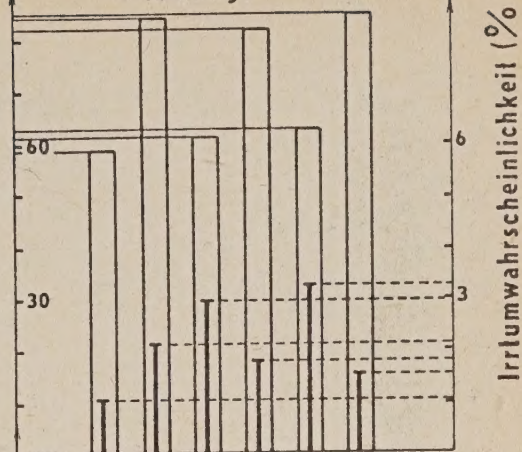
In vielen Ländern untersucht man in industriellen und urbanen Gebieten chemische Zusammensetzung und physikochemische Eigenschaften vom Wasser der Niederschläge aller Art. Es wurde nachgewiesen, dass das Niederschlagswasser solcher Gebiete - unabhängig von der Art des Niederschlages mit Schwermetallen belastet sind und eine deutlich saure Reaktion aufweisen (PALUCH, 1966; BARKMANN, 1968; NOVÁKOVÁ, 1973; CRUPA, COSCIO, WOOD, 1974; LAGERWERFF, 1974; HUGSTROM, 1974; ANYZ, PRIBIL, 1974; MINGES, 1975; KASSLER, 1976; BROWN, 1977; WOJTASZEK, 1977; ŻUKOWSKA-WIESZCZEK et al., in press; ŻUKOWSKA-WIESZCZEK, 1980; HILL, ADAMOWICZ, 1977).

Abb. 1. Abhängigkeit zwischen dem Triebn and Wurzellanges der Pflanzen und dem Einfluss des Niederschlagswassers von verschiedenen Messpunkten in Warschau. 1, 3, 5 - Strassenbereich, 2, 4, 6 - in den Parks.

Wurzellänge

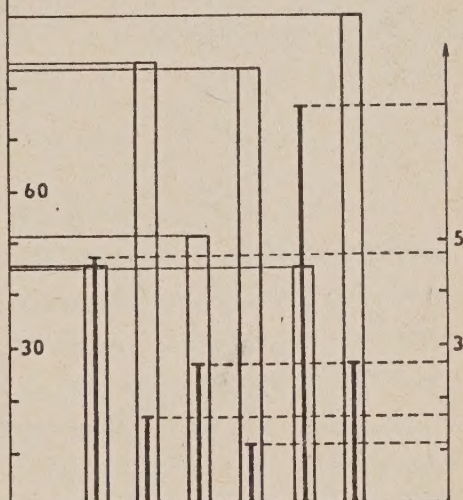
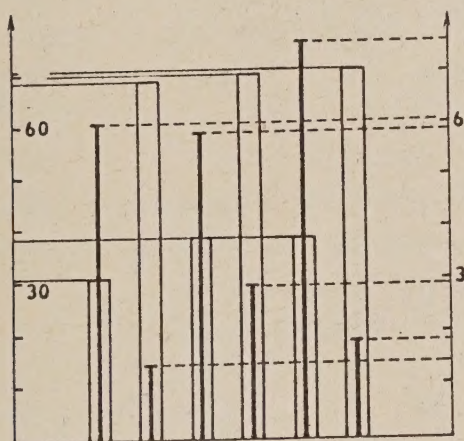


Trieblänge

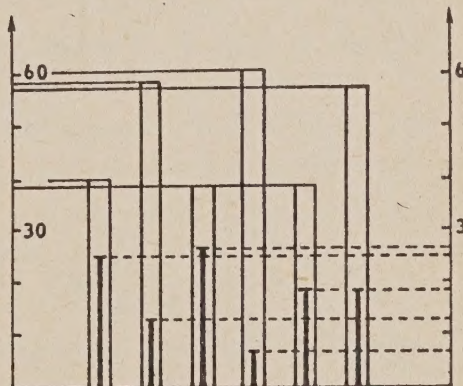
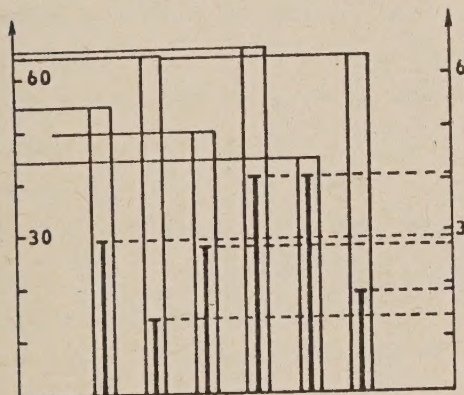


Irrtumswahrscheinlichkeit (%)

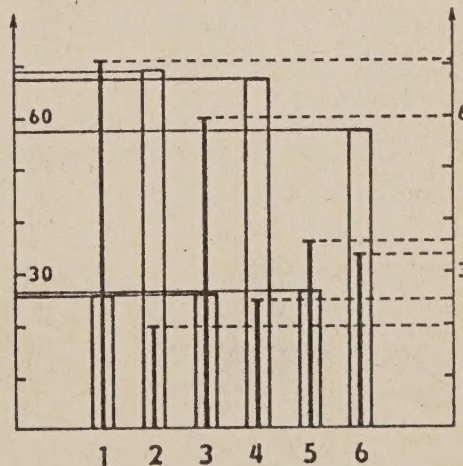
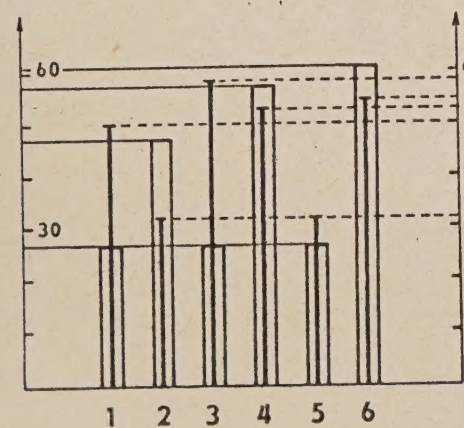
Pekinese Kohle



Rettliche



Rote Beete



Erbse

Tab. 1. Reaktion und chemische Zusammensetzung des Niederschlags Wassers von Warszawa (in ppm).
+ Strassenbereich, ++ in Parks

Messpunkte	pH im H ₂ O	Ca	S(SO ₄)	Cl	Na	K	Mg	Mn	Zn	Pb
ul. Marszałkowska ⁺	4,0	20,0	7,0	3,6	3,6	2,6	1,3	0,1	0,05	0,06
Ogród Saski ⁺⁺	5,0	6,8	3,0	0,8	1,9	0,9	1,5	0,1	0,00	0,00
al. Świerczewskiego ⁺	3,9	18,0	8,0	3,2	2,6	3,5	1,7	0,2	0,09	0,08
Park Praski ⁺⁺	5,4	10,0	5,0	2,0	1,9	1,2	1,2	0,2	0,00	0,00
al. Żwirki i Wigury ⁺	3,7	5,4	8,5	1,8	5,3	2,8	2,0	0,2	0,10	0,09
Cmentarz Żołnierzy Radzieckich ⁺⁺	5,2	5,4	6,0	1,4	3,3	0,7	1,3	0,2	0,06	0,00
alle messpunkte im Strassebereich	3,7- -4,0	5,4- -20,0	7,0- -8,5	1,8- -3,6	2,6- -5,3	2,6- -3,5	1,3- -2,0	0,1- -0,2	0,05- -0,10	0,06- -0,09
alle messpunkte im Parken	5,0- -5,4	5,4- -10,0	3,0- -6,0	0,8- -2,0	1,9- -3,3	0,7- -1,2	1,2- -1,5	0,1- -0,2	0,00	0,00

Es steht fest, dass die oben angeführten Faktoren d. h. Belastung mit Schwermetallen und gleichzeitige Versäuerung des Niederschlagswassers als Folge u. a. von SO₂ und NO_x einen synergistischen und sumariischen Effekt auf das Wachstum der Testpflanzen hervorrufen.

Die niedrigeren pH-Werte des Niederschlagswassers aus dem Strassenbereiche und die früher beobachtete Versäuerung des Schnees (ŻUKOWSKA-WIESZCZEK et al., in press) konnten für die Inhibition des Sämlingwachstums verantwortlich gemacht werden. Gleichzeitig ist die Tatsache zu berücksichtigen, dass eine Versäuerung des Wassers eine gesteigerte Aufnahme der Schwermetalle durch Wurzelsystem wie z. B. Pb und Zn verursacht.

Von grosser Bedeutung scheint die erhöhte Menge der Cl-Ionen und Ca, Na und K-Kationen im Niederschlagswasser aus dem Strassenbereich zu sein. Diese Erscheinungen überlappten sich und wirkten sich negativ in erhöhten Masse. Die Ergebnisse deuten darauf hin, dass unter grossstädtischen Bedingungen eine zusätzliche Verunreinigung der Pflanzen durch Niederschläge herbeigeführt sein kam. Ausser durch Stomata muss auch die Schadstoffaufnahme durch Wurzelsysteme berücksichtigt werden. Die Anwendung von Pflanzentesten und Beobachtung ihrer ersten Entwicklungsstadium scheint für die Diagnose der Luftverschmutzung und Belastung des Niederschlagswassers völlig begründet zu sein.

Auf Grund der Beobachtungen über Empfindlichkeit und Drauchbarkeit der Testpflanzen gegenüber den Schadstoffen im Niederschlagswasser von Warszawa wurde folgende Reihenfolge festgestellt:

Rettich, Rote Beete, Erbse und Pekinense Kraut von den vier Testpflanzen können wegen ihrer grossen Empfindlichkeit gegenüber der Belastung des saueren Niederschlagswassers mit den Schwermetallen und Cl, Ca, Na, und K nur Rettichen und rote Beete gute diagnostische Dienste leisten.

Die Verfasserin dankt Herrn Dr. H. Gozłinski vom Labor der Physiko-Chemischen Analyse der Landwirtschaftlichen Universität in Warszawa für die Durchführung der chemischen Analysen des Niederschlagswassers.

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Indication of nitrogen fertilization by weeds

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It is very difficult to distinguish the effect of single nutrient on plant growth from the other ones in the field. In addition, it seems impossible to separate the direct influence of the resource under the question from the indirect one. As pointed out by HARPER (1977, p. 340), "a major effect of supplying nutrients to vegetation may simply be to speed up the time at which light becomes limiting. Similarly the application of nutrients may make possible a greater growth of roots which are then capable of tapping water resources. The existence of these interactions makes it difficult to interpret fertilizer experiments." There are only a few examples of truly dependence of plant growth on nitrogen resources documented in the literature up to now (LANG et al., 1956 sec. HARPER, 1977). The interference between weeds and crops is another factor bringing more complexity to the biological indication of soil conditions (KOCH, 1967; GLAUNINGER, HOLZNER, 1982).

However, nitrogen can often be the limited nutrient because of its great mobility in the soil solution which results in local lowering of concentration or even depletion by the root absorption (HARPER, 1977; HOLZNER, NUMATA, 1982). Many authors described the remarkable influence of fertilization on weed communities (e. g. KOCH, 1957; ROLA, 1973; BOHNERT, 1981). Fertilization can lead to dramatic changes in the species composition and community diversity (TILMAN, 1986). The efforts streamlined towards specification of plant indicators of nitrogen amount in the soil have long tradition (WALTER, 1963; HEINRICH, 1973; ELLENBERG, 1979, etc.). Such indication can be understood as a negative response of the nitrophilous species to the shortage of nitrogen or as a damage of the strongly nitrophobic ones due to nitrogen overdose (WALTER, 1963). The indicator value of a species, however, depends on the whole complex of factors and may not be only different from area to area but also from plant community to plant community. It is only exceptionally, or with restrictions, possible to use weed species as indicator for the content of single nutrient in the soil, as emphasized by HOLZNER (1982).

This paper is based on the material obtained from an experimental barley field located near the village Samšín, district Pelhřimov, South Bohemia, in the region of moderately humid climate confined to highlands (elevation above sea level 500 m). For detailed description of natural conditions see PYŠEK et PYŠEK (1987). The field was divided into plots of 3.5 ha which were treated with $(\text{NH}_4)_2\text{SO}_4$, $\text{CaNH}_4(\text{NO}_3)_3$ or liquid urea (DAM). The amount of fertilizer applied was 70 and 140 kg of total nitrogen per hectare, respectively. Non-fertilized belts of the crop stand served us for the control. The weed community was estimated using randomly distributed plots of 1 x 1 m in which the vegetation was recorded by the seven-grade scale of Braun-Blanquet. The simple transformation to the numerical scale 1 - 7 enabled us to calculate the mean value which is called "mean dominance (d)" in Tab. 1. The frequency of species was calculated from their occurrence in plots investigated (MUELLER-DOMBOIS, ELLENBERG, 1974).

The species composition of the weed community is presented in Tab. 1. The species which exhibit an accessorial occurrence without obvious response to the fertilization were omitted. The total number of species recorded all over the field reached 44. Moreover, the table brings an attempt

Tab. 1. Species composition of the weed community investigated.

f - frequency, d - mean dominance, - ... species occurrence decreases with increasing dose of fertilizer, + ... species occurrence increases with fertilization; the slight response is indicated by parentheses.

Indicator values: N 7 - mostly in soils rich in mineral nitrogen

N 8 - nitrogen indicator (according to Ellenberg, 1979).

	N (kg . ha ⁻¹)						indicator		H-value
	0		70		140				
	f	d	f	d	f	d	presence	quantity	
Arenaria serpyllifolia	16	1.0	-	-	-	-	-	-	x
Vicia angustifolia	16	3.0	2	1.0	-	-	-	-	x
Equisetum arvense	16	1.0	4	3.5	-	-	-	-	3
Sonchus arvensis	5	1.0	11	1.8	-	-	-	-	7
Veronica arvensis	100	2.3	35	1.6	15	1.6	-	-	x
Tilaspia arvense	68	2.5	12	1.6	13	1.2	-	-	6
Medicago lupulina	63	2.6	9	1.0	11	1.0	-	-	x
Anagallis arvensis	26	1.6	2	2.0	4	1.5	-	-	6
Lamium amplexicaule	21	1.0	4	1.5	4	1.0	-	-	7
Fallopia convolvulus	79	2.0	70	2.1	33	1.4	(-)	-	x
Myosotis arvensis	95	2.2	67	2.3	54	1.9	(-)	-	6
Veronica persica	79	2.9	44	2.5	24	3.2	(-)	-	7
Galeopsis bifida	58	1.5	25	1.7	15	2.0	(-)	-	7
Viola arvensis	58	1.5	42	1.7	37	1.4	0	-	x
Stellaria media	74	2.7	67	3.4	76	4.0	(+)	-	8
Apera spica-venti	5	1.0	7	2.5	11	2.2	(+)	-	x
Galium aparine	53	1.6	82	3.4	89	3.0	+	-	8
Chamomilla suaveolens	-	-	5	1.0	2	1.0	(+)	-	8
Avena fatua	-	-	1	1.0	2	2.0	(+)	-	x

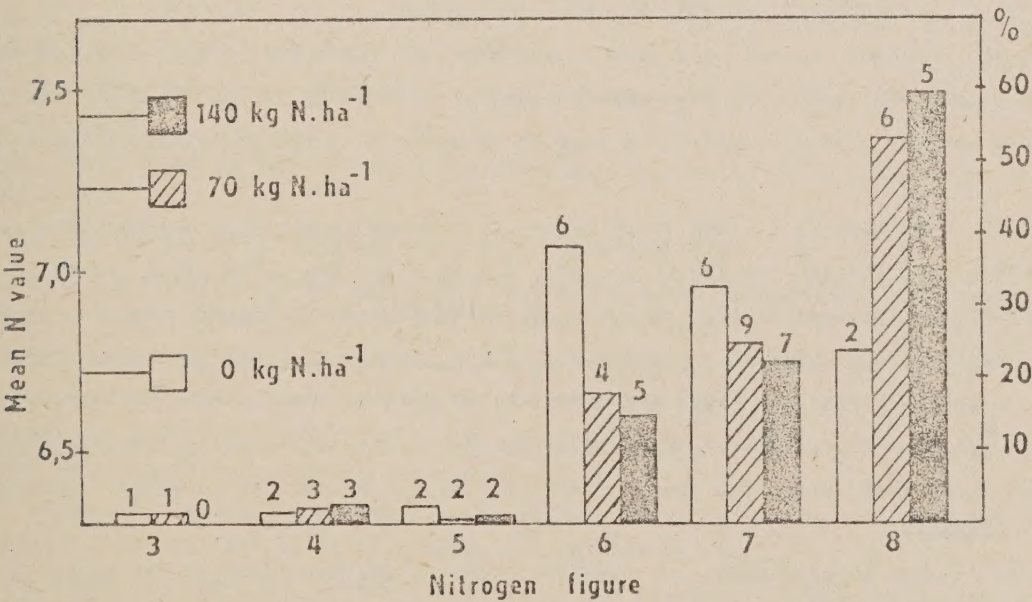


Fig. 1. Frequency distribution of N-indicator values for differently treated plots. Percentage proportion of the species with certain value is expressed on the right-hand scale. Numbers on tops indicate numbers of species present with the given value.

Tab. 2. Comparison of the properties of weed community in differently fertilized plots.

	N (kg . ha ⁻¹)			average
	0	70	140	
total number of species	29	34	30	44 (total)
mean number of species per relevé	8.8	5.2	4.5	5.7
species diversity H'	2.96	2.21	1.72	2.13
mean indicator value: L	6.17	6.42	6.30	6.32
F	4.73	4.86	4.52	4.72
N	6.72	7.23	7.43	7.20

to evaluate the indicator value of the species. The higher dose of nitrogen was found to suppress Veronica arvensis, Thlaspi arvense, Anagallis arvensis, Arenaria serpyllifolia, Vicia angustifolia and Equisetum arvense. On the other hand, the data allowed the following species to be considered the indicators of excessive fertilization: Stellaria media, Galium aparine, Apera spica-venti and Avena fatua. However, one must keep in mind the restrictions mentioned above (HOLZNER, 1982) when compiling such lists.

The presence of the species in the plots where 140 kg N . ha⁻¹ was applied is not only due to their nitrophilous character but also because of their life and growth form. This is the case of lianes Galium aparine, Fallopia convolvulus (cf. WILLMANS, 1983; GROLL, MAHN, 1986) and of the species creating tall individuals capable to grow successfully in the vigorous, luxuriant stand of the crop which is typical for these parts of the field (PYŠEK, PYŠEK, 1987). Good accordance of our results with the indicator values of ELLENBERG (1979) can be seen from Tab. 1: the nitrogen indicators (N 8) are concentrated in the part of the table containing species with increasing occurrence in the fertilized plots.

Ellenberg's indicator values were used to estimate the influence of environmental factors on the composition of weed community. Calculations of mean values for L (light), F (moisture) based on the species mean dominance were made to compare the differently fertilized plots (Tab. 2).

The species requirements of both light and soil moisture do not show any distinct relation to the fertilization treatment. On the other side, the mean N - indicator value increases obviously; presumably the nitrogen content is the decisive environmental factor (Fig. 1). As far as some other properties of weed coenosis are concerned, one can see rapidly decreasing average number of species per relevé and species diversity H' with increasing dose of nitrogen. The total number of species recorded is approximately the same in differently treated parts of the field which means that only a few species are strictly eliminated due to either shortage or surplus of nitrogen.

The fertilization brought about an increase of the height and cover of the barley population. The most conspicuous changes were recorded after the application of urea which lead to almost complete absence of weeds. The only exceptions to this rule were Galium aparine and tall grasses (Avena fatua, Apera spica-venti). The relationship between synmorphological features of the crop stand and the weed vegetation was analysed in the previous paper (PYŠEK, PYŠEK, 1987).

Some differences in the infestation appeared according to the type of the fertilizer; the results will be published elsewhere. The changes in the growth habit of some species were recorded in the overdosed plots: etiolation, increased in height and restricted branching and lateral growth are the typical properties of Myosotis arvensis, Viola arvensis, Thlaspi arvense and Veronica arvensis occurring in such habitat.

The colour of leaves of Galium aparine is changing to dark-green in plants growing in overdosed areas (PYŠEK, 1983). The barley responds in the same way; this can be used for remote sensing of fertilization effect on crops (e. g. STANHILL et al., 1972; PYŠEK et al., in press).

During the vegetational period, the infestation is the greatest where no dose of nitrogen was used. On the contrary, the opposite phenomenon was observed after harvest. The species possessing a creeping habit (Stellaria media, Veronica persica) are still thriving in the nitrogen-rich plots because of the more favourable moisture and nutrient conditions. In addition, their biomass is not completely removed by harvesting procedures. The flowering period is delayed, for the demands on light cannot be met in the ground layer of the dense crop stand. On the other hand, the species occurring mostly in non-fertilized plots are usually over the vegetation peak. The overdose areas can therefore be detected on aerial photographs by infestation contours as described by PYŠEK et al. (in press).

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The resistance of forest plants and communities to the recreation

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The recreational influence on the nature more and more provokes the increasing ecological damage. The species composition of vegetable communities and zoocenoses is changing, the evolutionary fixed consortive relations are disturbing, the protective and sanitary-hygienic functions of forest ecosystems are lowering, the attractiveness of landscapes is loosing. It is necessary to plan the intensity and the character of recreational forest-use, and for this aim one has to know the level and the specificity of anthropogenic tolerance of different kinds of forest plants and ecosystems as a whole.

Such investigations were carried out in the Laboratory of Forestry of the USSR Academy of Sciences. They were of complex character because the totality of natural processes was studied simultaneously: the changes in the composition and structure of vegetation, the post-recreational variability of litter and soils of different granulometric composition and with different type of water regime, the changes in the composition of soil microflora, algoflora and soil fauna and so on. The factual data were obtained which convincingly show how, due to the trampling down, the litter is disturbed and perished, the density of low soil levels is increased, the permeability to the water and the extent of aeration are decreased (particularly, in the soils formed on loams), the formed redox processes are disturbed, and as the result the soil biological activity is decreased. The quantity of the most groups of microorganisms is reduced to a fraction of its former value, and some species are completely disappearing. There is a significant change in the composition of complex of dominant soil algae - the presentation of various systematic groups and the character of species distribution according to the ecological groups. The change of ecological conditions is also indicated by the important shifts in the fauna of soil invertebrates.

During the investigations the recreational tolerance of more than 200 species of herbaceous plants was determined. The species were revealed which disappear from the communities' composition with a relative quick rate even at the low forest visiting; the another species are more hardy and are retained in the grass cover for a longer time; concerning the other species, the changes of phyto-environment occurring under the conditions of recreational forest-use are, within the known limits, favourable for them and promote their abundant occurrence and viability. We attach a great importance to these observations because many species could be used as the indicators of environment state, according to the qualitative and quantitative parameters of their populations one could assess the degree of disturbance of ecosystem and the possibility of its restoration.

About 20 plant species are attributed to the category of the most vulnerable species, including the whole of orchids. They don't tolerate the soil condensation, are easily damaged during the trampling down because of the fragility of ground surface sprouts and due to the unprotected buds of renewal, they attract the particular attention of visitors by their high decorativeness. The highest vulnerable species don't belong to some definite vital form;

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they include the tuber species (Corydalis) as well as the typical succulents (Jovibarba sobolifera) and the plants extended on the soil surface (Gycomodiaceae).

The species of the 2nd category - less vulnerable and more tolerant ones - as to the biomorphological respect, are as well not uniform. For example, two species which are of much popularity for the people at recreation (Anemona ranunculoides, A. aenorosa) belong to the group of short-rhizome ones, the moderate loads promoting their vegetative propagation stimulating the division of rhizome sprouts into the autonomous segments, each of them later forms the ground surface sprout. Another popular species (Pulsatilla patens) has the completely different type of underground morpho-structure. The powerful perennial rhizome, being deeply into a soil, is relatively resistant to the trampling down, the latter affects only the highest soil layer on the loose sandy soil where this species inhabits. But this species has another "weak point" - as the result of mass destruction of its beautiful generative sprouts, the seminal propagation is getting minimum, and the vegetative one is lacked. This leads to the "aging" of population with subsequent decrease of quantity and, finally, to the complete exclusion of species from the composition of grass cover. I need these examples to demonstrate that the determination of anthropogeno-tolerance for each plant species has to be strictly individual: on the one hand, the species belonging to the same bio-morph could differ significantly in the degree of their resistance to the recreational loads, and, on the other hand, the species, evidently differing in various indexes, similarly react to the recreational influence. This also concerns the species which appear in the forest together with "the man at recreation".

The "Floras" containing the descriptions of several species include more or less detailed characterizations of its following features: the geographical distribution, the ecological peculiarities, the morphology, the ontogenesis, the seasonal rhythm of development, the means of propagation and spreading, the phytocenotype and many other features; but, as a rule, there is a lack of description of its reaction to the anthropogenic influence (including the recreational one). However, at the present time, the influence of anthropogenic factors acquires the more and more wide scales and is getting the more and more intensive. Therefore, the study of anthropogeno-tolerance of some plant species, their relation to the another factors connected to the man's activities assumes the more and more importance. Only being possessed by the information of such kind, one could plan correctly the recreational forest-use and to restore what have been disturbed.

The total tolerance of species which compose the community is the important index of tolerance of ecosystem as a whole; but it is not the only index, because it is necessary to take into account the resistance of its another components. Being disposed by a large number of factual data, collected during some years in the forests of different kinds, on the sites with different degree of recreational influence, we are preparing two monographs. One of them will be a compendium on the recreational tolerance of different plant species, the another one will be a compendium on the recreational tolerance of the principal types of forest ecosystems from the centre of the Russian Plain. We hope that they will be not only of regional interest, but, perhaps, could stimulate the conducting of similar researches in another biomes, and, besides, not only in the forest ones.

Herb layer deterioration in a forest (North Hungary)

M. PAPP, P. JAKUCS, B. TÓTHMÉRÉSZ

INTRODUCTION

In 1972 a complex ecological research project began in North Hungary within the framework of a MAB program (JAKUCS, 1973). A climazonal healthy sessile oak - turkey oak forest (*Quercetum petraeae-cerris*) was chosen for the investigations. The research station is known as "Sikfűkút Project".

Since the late 1970's a wide-scale deterioration of oak forests has been observed in North Hungary in the highly industrialized part of the country. Our research station lies in this region.

At the beginning of the 1979's almost each structural parameter was registered in each community level on the one-hectare central plot of the research station (JAKUCS, 1985). So we could follow the changes induced by tree decay easily.

In the tree layer up to 1978 sixteen trees died on the basic plot owing to damage by wind and natural death. The speeding up of tree decay has been followed since 1978. Up to August of 1985, 47.8 % of the sessile oaks died and the symptoms of disease were observed in 17 % of the still living trees (JAKUCS et al., 1986). A remarkable change has taken place also in the shrub layer. Almost all *Quercus petraea* individuals of shrub-size have disappeared. Shrubs taller than 1 m have withered but those shorter than 1 m have increased in number (KÁRÁSZ et al., 1986).

Here we wish to present the processes induced by the above facts in the herb layer of the forest.

Studying the herbaceous layer we make comparisons from two points of view. First we compare two phytocoenological relevés taken on the forest stand in 1975 (PAPP, JAKUCS, 1976) and 1987. Then we compare the structural data of the herbaceous species of the central plot obtained between 1973 and 1975 (JAKUCS, PAPP, 1974; PAPP, 1979, we shall use the average figures as data from 1974) and those taken in 1982 and 1987.

RESULTS

Phytocoenological changes

The phytocoenological relevés were taken both in 1975 and in 1987 with the Braun-Blanquet and Soó combined technique (Soó, 1945) in 20 by 20 m squares in the forest stand. The data obtained were arranged in tables and evaluated on the basis of works done in Hungary (Soó, JÁVORKA, 1951; JAKUCS, 1961; Soó, 1964-1973; ZÖLYOMI et al., 1967). When making comparisons between the two tables we found that the characteristic species of xerotherm oak forest, *Potentillo-Quercion* and *Aceri-Quercion* species are present with very similar frequency in the table of 1987 too. The number of species increased significantly in the *Quercetea pubescenti-petraeae* group. Among these species there are many forest-steppe elements. The number of species in the "other" category containing species characteristic of other than oak forest communities has increased.

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Part of the species in this group is the festuco-Brometea species, and the number of common weeds is also relatively high. The number of species in the table of 1975 was 91 and that of 1987 was 130. Comparing the two enumerations 13 species disappeared whereas 52 new species appeared in the table of 1987. The number of the common species is 78. The Jaccard's similarity between the two series of phytocoenological data is only 0.545, that is similarity is hardly greater than 50 %.

We calculated the average TWR indicator numbers (ZÖLYOMI et al., 1967) according to the group ratio. The mean of T numbers reflecting the temperature relations and the mean of the W numbers reflecting the water regime conditions have not changed significantly during the 11 years. The mean of R numbers reflecting soil pH slightly decreased by 1987 but this figure (3.29) still does not reflect acid soil. However, considering the 52 species' mean R number appearing by 1987 it is significantly lower, indicating slightly acid soil conditions.

There was no change in flora-element distribution during this period. Considering the life from distribution among the species, we found that the ratio of geophyte has dropped and at the same time that of therophyte has increased significantly. Ultimately, the above facts together reflect the changes in ecological factors following tree decay.

STRUCTURAL CHANGES

The registration of the structural characteristics of the herb layer was carried out partly on the basic model hectare of the research station (the number of individuals and the cover values), partly in an area allotted for destruction (samples for phytomass and production investigations).

In 1974 the forest was characterized by eleven herb species: Poa nemoralis, Melica uniflora, Carex michelii, Carex montana, Dactylis polygama, Festuca heterophylla, Galium schultesii, Fraxania vesca, Lathyrus niger, Lathyrus vernus, Chrysanthemum corymbosum in order of importance. The role of the further 15 species in the "others" category was very low in those years. The cover of the herb layer was 31.8 %. Poa nemoralis and Melica uniflora predominated in every respect.

There have been appalling changes in the structural data since 1974 (Tab. 1, Fig. 1, 2). The individual numbers dropped remarkably to about 709 thousand per ha in 1982 and to 41 thousand in 1987 from more than one and a half million (Fig. 1).

The figure for 1987 is only 2.7 % of that observed in 1974. At the same time the species number in the "other" category increased by 41 species. Their individual numbers taken together make up of 30 % of the total individual number and 32 % of them are therophyte.

In 1974 Poa nemoralis and Melica uniflora predominated together with two Carex species. In 1987 Poa nemoralis was replaced by Melica uniflora and Geranium robertianum and Galium schultesii were the next in the order of importance.

The total cover of the herb layer was reduced too, but not to as great an extent as was the individual number. It means that the species replacing the original ones have larger foliage.

To estimate the phytomass we used partly the average weights measured in 1974 in the case of 8 species, and also collected species having more than 5 individuals on a hectare to weigh.

The total phytomass (Tab. 1, Fig. 2) of the herbaceous layer was 568.89 kg/ha in 1974 and only 23.23 kg/ha in 1987. In 1974 and in 1982 eleven species made up more than 95 % of the total phytomass. In 1987 they came to only 57 %. The distribution of phytomass among the species has been rearranged as we saw in the case of the individual numbers.

The ratio of underground and aboveground phytomass increased from 1.1 to 1.47. It means that the species predominating in 1987 have larger or heavier root systems or rhizomes.

The above-mentioned changes in the structural data can be exposed in diversity values too. The corrected Shannon diversity of species-individual was 0.472 in 1974 and 0.845 in 1987. The species-phytomass diversity in 1987 was much higher: 1.05.

The value of evenness, too, increased from 0.3190 to 0.5008, that is the herb layer now cannot be characterized with the structure evolved in the course of decades and observed in 1974. The distribution of the individuals of species is relatively in balance. The importance of some species dropped and the species number increased significantly.

This presentation aims at calling attention to the damage of the herbaceous vegetation, which sometimes does not appear to be so important as woody plants in the study of regional deterioration. Obviously, it is of no direct economic benefit. However, it constitutes an organic part of a forest, and the negativ changes in this layer, too, are by no means negligible contribution to our lossess.

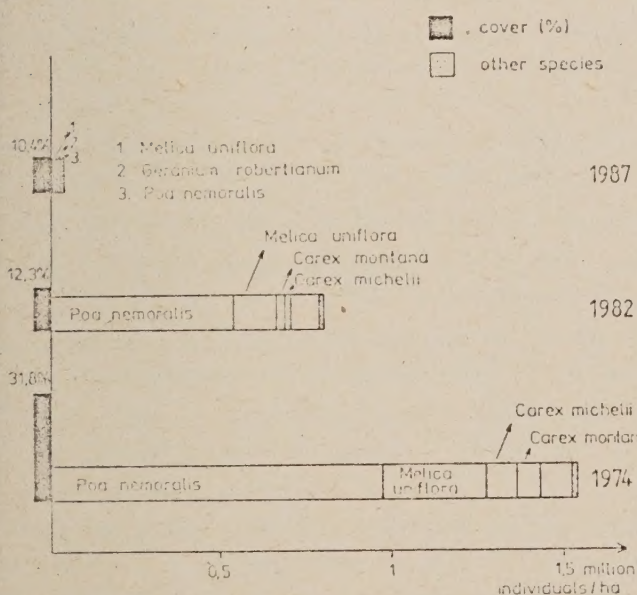


Fig. 1. Changes in the individual number and cover of the herb species on the studied basic hectare in Sikfökút.

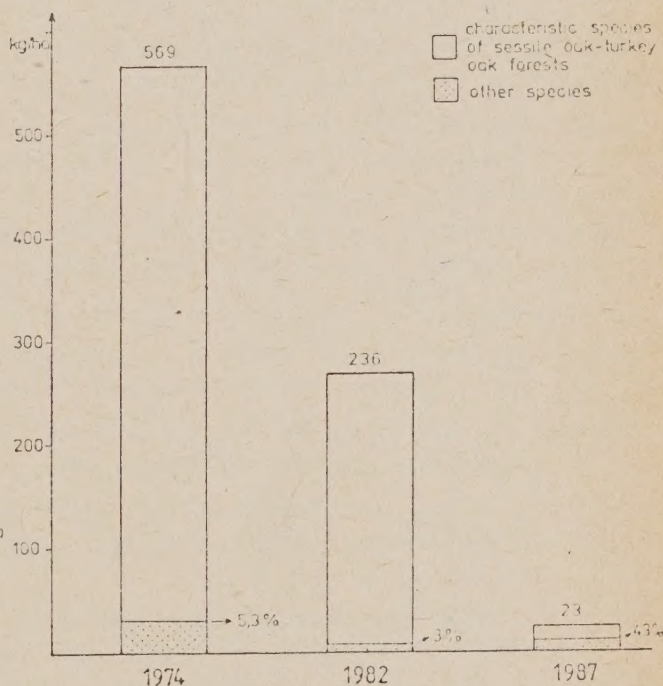


Fig. 2. Herbaceous phytomass and its composition in Sikfökút.

Tab. 1. Changes in the structural data of the herb layer during 13 years (A = data of species characterizing the oak forest; B = data of "other" species; C = total; a = above ground phytomass; b = underground phytomass; c = total).

			1974	1982	1987
individual numbers/ha	A		1518240	707539	28460
	B		20347	1499	12524
	C		1538587	709038	40984
cover %	A		30.35	10.39	3.57
	B		1.43	1.92	6.85
	C		31.78	12.31	10.42
phytomass kg/ha	A	a	255.64	112.10	5.73
		b	283.31	116.88	7.48
		c	538.95	228.98	13.21
	B	a	15.73	3.36	3.66
		b	14.21	3.51	6.36
		c	29.94	6.87	10.02
	C	a	271.37	115.46	9.39
		b	297.52	120.39	13.84
		c	568.89	235.85	23.23

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Damage estimation of an oak forest (*Quercetum petraeae-cerris*)

B. TÓTHMÉRÉSZ, P. JAKUCS

INTRODUCTION

There has been widespread forest damage in Europe in recent years. In some cases the amount of tree decay is considerable. The biological and economic consequences of such a forest damage might be extremely serious.

In this paper the dynamics of tree decay and the amount of forest damage are estimated in the case of an oak forest (*Quercetum petraeae-cerris*). We also compared the height and the trunk diameter of the dead and healthy sessile oak (*Quercus petraea*) populations. This type of oak forests is typical in Hungary's hilly regions. It is a zonal forest community, and has a great extension: nearly half of the Hungarian hilly and mountainous regions are now, or were once, covered by this type of forest.

SAMPLING AREA

In our studies we used the data of the "Sikfűkút Project" Research Program (JAKUCS, 1973, 1978, 1985). The sampling area is in the hilly region of the Bükk mountains, which is a member of the North Hungarian Mountains. The research area is about 63.76 hectares ($6.376 \cdot 10^5 \text{ m}^2$) which lies along a latitude of $47^\circ 50'$, longitude of $20^\circ 46'$ and altitude of 320 - 340 m above sea-level.

A basic quadrat of 100 by 100 m forms the central part of the area, which is divided into several plots. These plots facilitate the separate investigation of various biological or ecological parameters. Our calculations are based on the data of this basic quadrat. The trees were marked on their trunks and all of them were counted and mapped.

The sampling area is covered by a sessile oak - turkey oak association (*Quercetum petraeae-cerris*). The dominant tree species of the forest community is *Quercus petraea*. In the tree layer *Q. cerris* is also present. The most frequent shrub species of the forest are *Cornus mas*, *C. sanguinea*, *Acer tataricum*, *Ligustrum vulgare*, *Crataegus monogyna*, *Euonymus verrucosus*; the frequent herbs are the following: *Poa nemoralis*, *Melica uniflora*, *Carex montana*, *Carex mixhelii*, *Pactylis polygama*, *Fragaria vesca*, *Lathyrus niger*, *Galium schultesii*.

METHODS

One of the most frequently used dissimilarity index is the so-called Bray-Curtis dissimilarity (BRAY, CURTIS, 1957):

$$D_{ij} = \frac{\sum_{k=1}^n |x_{ik} - x_{jk}|}{\sum_{k=1}^n (x_{ik} + x_{jk})}$$

where x_{ik} and x_{jk} are the number of individuals of the k -type object in the i -th and j -th samples; $k = 1, \dots, n$; $i, j = 1, \dots, t$.

SIGLEO (1975) proposed the following similarity coefficient:

$$s_{ij} = \frac{1}{n} \sum_{k=1}^n \frac{\min(x_{ik}, x_{jk})}{\max(x_{ik}, x_{jk})},$$

where "min" and "max" denote the minimum and maximum, respectively, of the values between the parenthesis. PINKHAM et PEARSON (1978) also used this similarity index in a biological context. See also ROMESBURG (1984), and WASHINGTON (1984).

The standardized Euclidean distance function in this paper was used in the following form:

$$d_{ij} = \left[\frac{\sum_{k=1}^n (x_{ik}^{st} - x_{jk}^{st})^2}{4 \cdot n} \right]^{1/2},$$

Where

$$x_{ik}^{st} = \frac{x_{ik} - \bar{x}_i}{s_i}, \quad \bar{x}_i = \sum_{k=1}^n x_{ik} / n, \quad s_i = \left[\sum_{k=1}^n (x_{ik} - \bar{x}_i)^2 / (n - 1) \right]^{1/2}.$$

In this form the standardized Euclidean distance is practically defined on the range $0 \leq d_{ij} \leq 1$, and virtually it is a dissimilarity index.

To the cluster analysis the distance of the states of forest was computed by the Bray-Curtis dissimilarity, and the weighted arithmetic average clustering method was used to fuse the "forest states" (e. g. LEGENDRE, LEGENDRE, 1983).

The principal component analysis was carried out on a correlation matrix (LEGENDRE, LEGENDRE, 1983; PIELOU, 1984).

RESULTS

The amount of tree decay is larger than 50 % in the case of sessile oak population. The number of trees in 1973 was 641 in the sampling quadrat; in 1987 304 tree individuals were alive and 338 were dead. This is a loss higher than 50 %. The dynamics of decay is presented in Tab. 1.

We have studied the distributional pattern of tree individuals. The change in distributional pattern is measured by dissimilarity functions. This gives an estimate of forest damage. The distribution pattern, in this case, has a niche theoretical explanation (TÓTHMÉRÉSZ, 1986). According to the dissimilarity functions the difference between the "state of the forest" in 1987 and the state of 1973 is more than 50 % (e. g. by the Bray-Curtis dissimilarity the difference is 0.5694, i. e. 56.94 %) (Tab. 2).

The result of cluster analysis suggests that on the "Sikfűkút Project" tree decay began in 1979. There are two distinct clusters: in the first group are the forest states of 1973 and 1974 - 1978; in the second one the years after 1979. In this second group there are two well-distinguishable subgroups (Fig. 1).

Tab. 1. Amount of tree decay in the case of sessile oak (*Quercus petraea*). A: number of healthy trees; B: total number of dead trees; C: percent of dead trees; D: absolute value of yearly decay; E: percent of yearly decay.

	A	B	C	D	E
1973	641	-	-	-	-
1974 - 78	627	14	2.2 %	14	2.2 %
1979 - 80	526	115	17.9 %	101	16.1 %
1981	491	150	23.4 %	35	6.7 %
1982	477	165	25.7 %	14	2.9 %
1983	452	190	29.6 %	25	5.2 %
1984	407	235	36.7 %	45	10.0 %
1985	348	294	45.9 %	59	14.5 %
1986	323	319	49.8 %	25	7.2 %
1987	304	338	52.7 %	19	5.9 %

The results of principal component analysis also confirm these statements. The distance between the points representing the 1973 and the 1974 - 1978 states of the forest is small (Fig. 2). There was only a small change in the "state of the forest". After 1978 the changes are more intensive. The distances between the points in the two-dimensional principal component space is summarized the Tab. 3.

The mean characteristics (height and trunk diameter were studied) of the dead *Qu. petraea* population were smaller before the tree decay (tab. 4). After 1979 there is no significant difference between the characteristics of the dead and the healthy populations. It can be seen that the characteristics of the trees that died before 1978 are significantly smaller than those of the total population it is also evident that the trees that died after 1979



Fig. 1. Dendrogram obtained by cluster-analyzing the "forest stages", which were characterized by the distributional pattern of the dominant tree species (*Quercus petraea*). The Bray-Curtis dissimilarity index and the weighted arithmetic average clustering method were used.

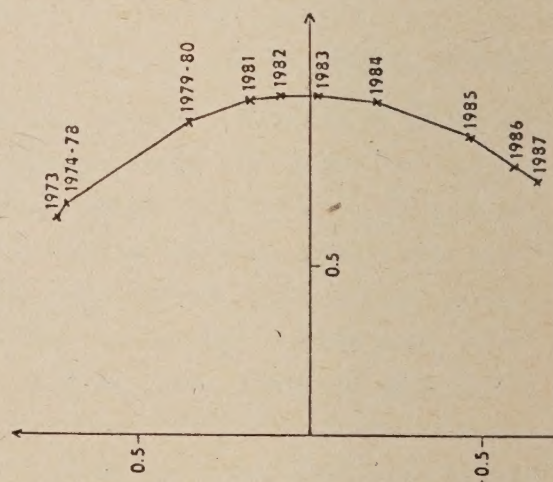


Fig. 2. Result of the principal component analysis. The PCA was carried out on the correlation matrix of the distributions of the dominant tree species (*Quercus petraea*).

Tab. 2. Estimation of forest damage by Bray and Curtis's Sigleo's, and standardized Euclidean dissimilarity functions. The estimates are based on the change in the distributional pattern of the dominant tree (*Quercus petraea*). The values show the distance from the "original" 1973) state."

	Bray-Curtis	Sigleo	Standardized Euclidean
1973	0.0000	0.0000	0.0000
1978	0.0486	0.1175	0.1866
1980	0.2153	0.4496	0.4089
1981	0.2708	0.5309	0.4259
1982	0.3056	0.5604	0.4470
1983	0.3403	0.5998	0.4649
1984	0.3889	0.6352	0.5248
1985	0.4861	0.7485	0.5949
1986	0.5417	0.7749	0.6345
1987	0.5694	0.7920	0.6591

Tab. 3. Dynamics of forest decay calculated by principal component analysis. A: distance from the state of 1973 in the two dimensional principal component space; B: distance from the state of previous year.

	A	B		A	B
1973	0.0000	0.0000	1983	0.8253	0.0991
1978	0.0458	0.0458	1984	0.9888	0.1812
1980	0.4706	0.4285	1985	1.2179	0.2865
1981	0.6553	0.1907	1986	1.3329	0.1507
1982	0.7351	0.0883	1987	1.3881	0.0828

Tab. 4. Trunk diameter and height of sessile oak trees (*Quercus petraea*) in the sample area.

	Average height (metre)	Average trunk diameter (cm)
Total population in 1973	17.33	20.15
Died before 1978	13.79	15.41
died in 1979-80	17.30	19.61
Died in 1981	16.92	22.13
Died in 1982	17.13	22.39
Died in 1983	17.05	19.62
Died in 1984	18.00	21.78
Died in 1985	19.78	18.11
Died in 1986	17.21	18.34
Died in 1987	16.58	19.74

did not show characteristics significantly different from the total population. This suggests that the process was "natural" before 1979. The relatively underdeveloped individuals died because of competition and other processes. The data of Tab. 1 also confirm this statement. From 1973 to 1978 only 14 Qu. petraea tree individuals died. So the process was extremely limited. In 1979-80, after the beginning of tree decay, 101 oak tree individuals died.

The forest is the most complex ecosystem in the biosphere and plays a significant role in the maintaining the stability of the entire biosphere. It is generally accepted that stability and complexity are closely related concepts (MAY, 1973). In natural or semi-natural forest ecosystems serious tree decay results in gaps in the forest structure; or more exactly, empty niches arise in the niche space. Vacant positions (empty niches) can be filled in by certain weeds and other r selectionists. This process may facilitate the reduction of species richness. At the same time, there is considerable reduction in the gene-pool of the dominant tree species; simply because of the considerably reduced population size (VIDA, 1978). When the genetic diversity of the population of the dominant species is small, it cannot evolve new adaptive gene-combinations in a relatively short time and, in general, cannot adapt itself to varying environmental conditions (CROW, KIMURA, 1970; MURRAY, 1972).

All these processes might result in reduction of the complexity and stability of ecosystems. So, on a global scale, forest decay threatens not only the own stability of forest ecosystems but also that of the entire biosphere.

S U M M A R Y

The dynamics of forest decay and the amount of damage are estimated by elementary and multivariate statistical methods in the case of an oak forest (Quercetum petraeae-cerris) in the "Sikfűkút Project" Research Area.

Our results suggest that decay might have begun in the research area in 1979. The damage to the forest is about 50 %, and there is no unambiguous sign of the deceleration of tree decay.

The amount of damage is large and the result might be catastrophic to the working mechanism of the forest ecosystem.

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Phytoindication stand evaluation of Medvědí skála and Liščí vrch in the Krušné hory (Ore Mts.)

I. HANOUSKOVÁ, E. HADAČ, J. LEPŠ

The possible uses of Ellenberg's phytoindication indices (ELLENBERG, 1974), which are useful in stand (habitat) possibilities estimations and descriptions, are presented. The goal is objective decision-making:

1. In the location of planting in forest recultivations
2. In defining initial data for managed diaspore transfer proposals due to biota stabilization in landscape.

MODEL AREA

Medvědí skála and Liščí vrch in the Krušné hory (Ore Mts.). Most of the area is formed by stony debris of weathered rocks (rough-grained gneisses) and by side-slope soils of various thickness (SAMEK, KRÁTKÝ, 1960). Peaty soils and rock exposures also occur, although are less frequent.

The vegetation cover is formed by remains of the preceeding anthropogenic climax, which had been formed by cultural spruce and beech forests. The plant layer of these remnants can still be detected in the new spruce, larch, pine, beech, crane and alder plantings (of various ages, cultivated under various technological conditions). The dominant grass is Calamagrostis villosa, which has dominated in recultivated calamity-clearings for the last 20-30 years.

ANALYSIS AND PRACTICAL APPLICATIONS

1. The vegetation system unit analysis (Fig. 1),
2. the interspecies relations (cf. SLAVÍKOVÁ, 1987) and
3. stand units with properties estimated on the vegetation species (and groups of them) background (Fig. 2), can be used together with
4. known autecological species demands (Tab. 1), in the creating for the purpose-aimed vegetation structure in local-landscape extent.

REACHED RESULTS IN MODEL AREA AND DISCUSSION

Estimations of stand possibilities was elaborated on the basis of Ellenberg's value screen (ELLENBERG, 1974).

An initial step in decision making is enabled by comparing Fig. 2 and Tab. 1. The same process may be used in decisions about wild plants re-introduction.

It is necessary to consider whether an unfavourable "offer" of a non-limiting factor (or group of factors) can be compensated by favourable conditions "offered" by others.

For the purpose of forest recultivations it is necessary to connect these estimations with forest plantation methods, elaborated from the forest typology point of view (in PLÍVA et PRŮŠA, 1969).

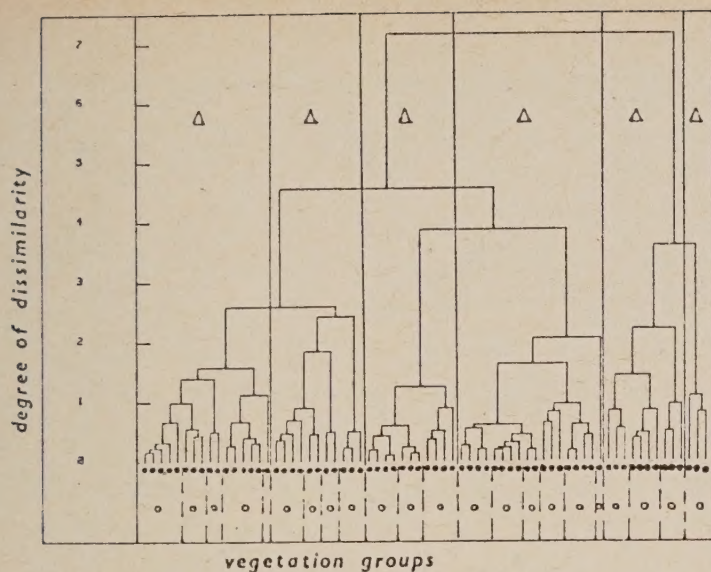


Fig. 1. The spectrum of actual vegetation groups are identified according to KUBÍKOVÁ (1971). They are ordered on the phytocenological record classification basis (dissimilarity by Euclidean distance). Resulting groups indicate stand pattern supply (Fig. 2) in model area. Data were processed by J. Lepš (LEPŠ, 1984).
 ● - phytocenological record
 ○ - group of phytocenol. records
 △ - group of phytocenol. records

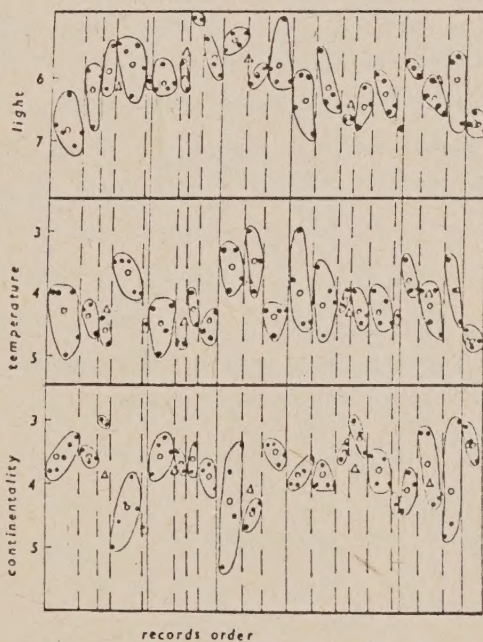
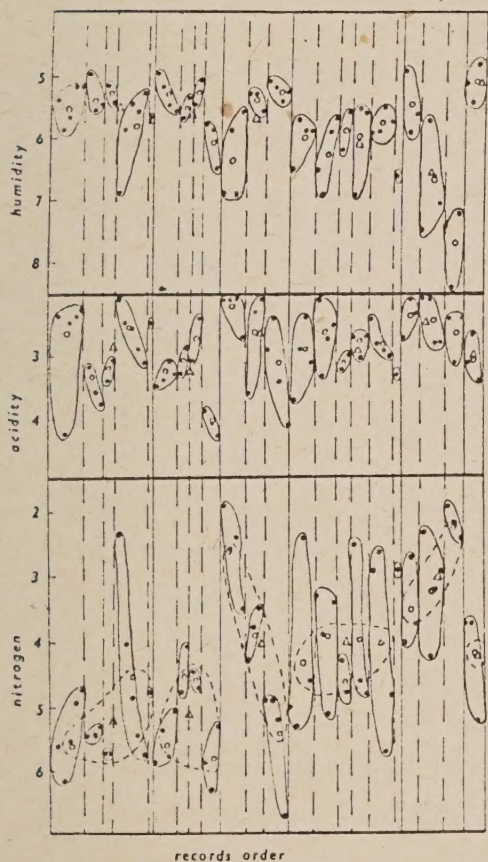


Fig. 2. The actual state dispersion of stands is described in relation to classification results (cf. Fig. 1). Phytoindication estimation was elaborated for:
 a) stand level of each phytocenological record (● - mean value)
 b) stand patterns developed according to history of stand evolution including land-use (○ - mean value)
 c) major vegetation groups - groups of stands (separated on high degrees of dissimilarity (△ - mean value)).

For estimation of stand "offer" possibilities with respect to light, temperature, continentality, rhizosphere humidity, acidity and available nitrogen were Ellenberg's mean values (ELLENBERG, 1974) exploited.

Tab. 1. Ellenberg's indices (ELLENBERG, 1974) according to trees cultivated in model area.

tree species	light	temperature	continen- tality	soil humidity	soil acidity	soil nitrogen
spruce (<i>Picea abies</i>)	5	3	6	x	x	x
pine (<i>Pinus silvestris</i>)	7	x	7	x	x	x
larch (<i>Larix decidua</i>)	8	x	6	4	x	3
beech (<i>Fagus silvatica</i>)	3	5	2	5	x	x
crane (<i>Sorbus aucuparia</i>)	6	x	x	x	x	x
birch (<i>Betula verrucosa</i>)	7	x	x	x	x	x
willow (<i>Salix caprea</i>)	7	x	3	6	7	7
alder (<i>Alnus glutinosa</i>)	5	5	3	9	6	x

To approximate the results in a large area, remote sensing data are suitable. In the given area large-scaled aircraft photos (1 : 3000) can be used.

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An example of bioindication on a large scale: mapping of lichens in Czechoslovakia

J. LIŠKA, J. PIŠŮT

Lichens as the most susceptible organisms to air pollution have been used till now for various purposes of bioindication. First mentions of lichen sensitivity were published in the 18th and 19th centuries, but a period of systematic investigations of lichen floras of some European cities started in the beginning of the 20th century (cf. HAWKSWORTH, 1971; LAUNDON, 1973). Relation between lichens and air pollution had been studied in detail during the last three decades: lichens were mapped in vicinity of industrial plants, various methods of zonation (e. g. the IAP method) were proposed, fumigation experiments in laboratory were performed, attention was paid to physiology of pollution effects etc. (cf. FERRY et al., 1973; RICHARDSON, 1988). At present, there are abundant data on distribution of lichens around diverse pollution sources concerning selected areas. But situation in more extended areas, e. g. in the whole country, is known poorly and it is very often based on data of a wide interval of time. Also distribution of rare lichens we know better than distribution of common species. Nevertheless, distribution of common epiphytic lichens and mainly their changes in time are very important for monitoring of environmental changes. For this reason, project of the mapping of present distribution of lichens was accepted in some European countries. Mapping method uses a grid system.

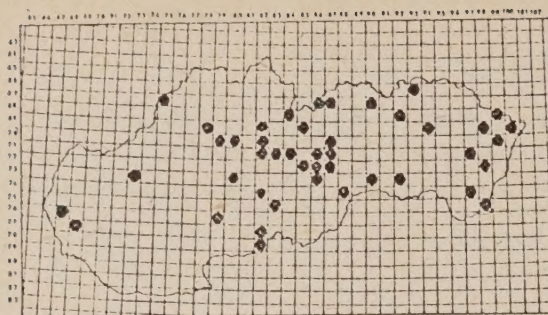
In Czechoslovakia, as in West Germany, Austria and Switzerland (cf. WIRTH, 1984), were used coordinate grid squares 10' x 6', i. e. the same as for mapping of higher plants, birds etc. For reasons of lichen sensitivity as well as for want of persons, mapping was limited to epiphytic lichens only. Mapping of epiphytic lichens in Slovakia started in 1975, in Bohemia and Moravia in 1978; in both cases records from 1970 onwards were accepted.

The maps of distribution are the basic result of grid mapping of lichens. In large areas we can demonstrate influences of various factors (e. g. climate, altitude, substrate). Especially we can indicate landscape deterioration, namely air pollution impact. The most evident is sulphur dioxide effect resulting in an acidification of environment. If we compare maps of different lichens, we find toxitolerant and sensitive species with different degree of sensitivity. On this comparison it is possible to propose a scale of bioindicators. Because mapping in western part of Czechoslovakia is still run we are able to demonstrate results of mapping in Slovakia which includes records from 1970 - 1981 period (PIŠŮT, 1985) (Fig. 1).

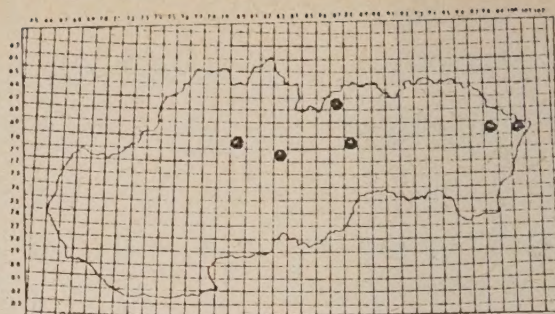
The main factor responsible for decline of majority of lichens is the combined effect of various factors as air pollution, changes in forest management, use of fertilizers and pesticides in agriculture etc.

Besides an air pollution impact, it is possible to indicate also effects of an intensive agriculture. Negative consequences are evident in case of distribution of nitrophobous species, e. g. absence of Hypogymnia physodes in Podunajská nížina lowland is caused by high concentrations of nitrogen compounds and elevated eutrophication of bark. On the other hand, a positive effect is evident on distribution of Buellia punctata (Fig. 1).

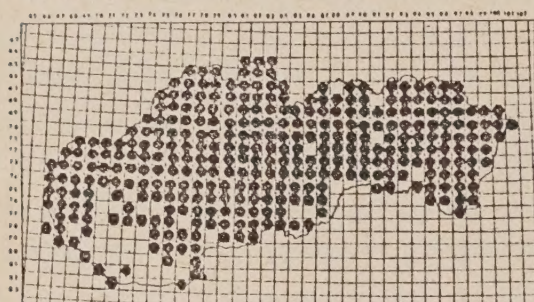
Ramalina farinacea



Menegazzia terebrata



Hypogymnia physodes



Buellia punctata

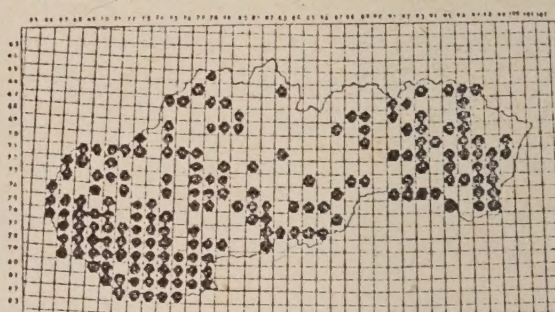


Fig. 1. Distribution of selected lichen species in Slovakia (1970 - 1981).

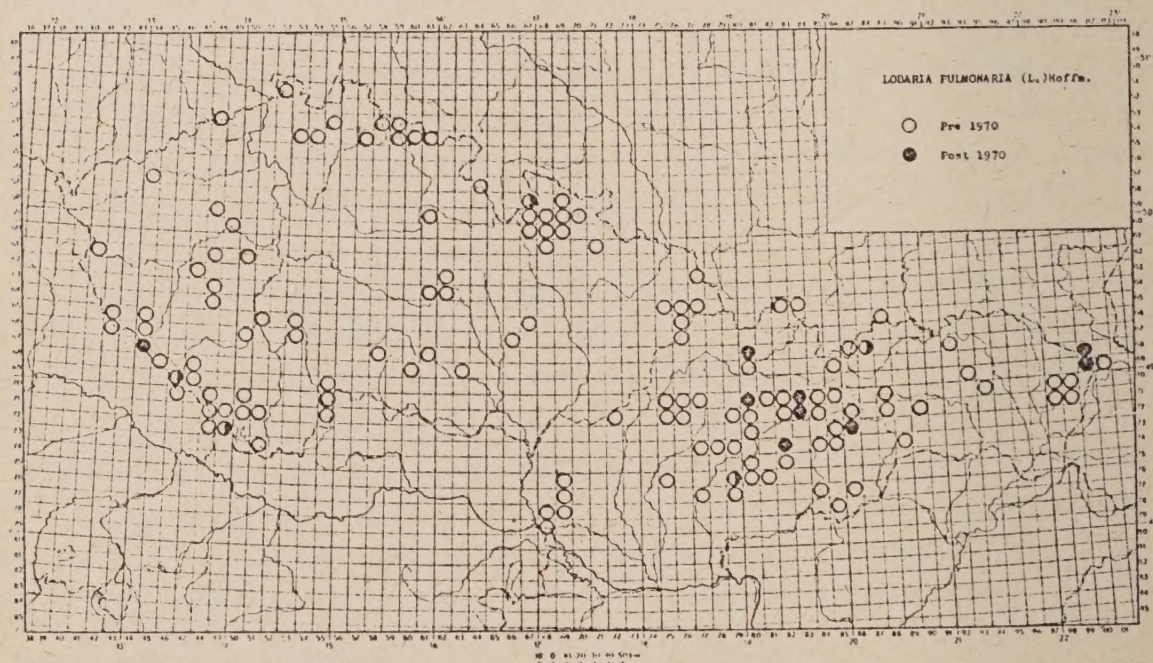


Fig. 2. Changes in Czechoslovak distribution of *Lobaria pulmonaria* in two periods.

Other use of mapping is in involving of time for assessment of dynamics. Lichen Lobaria pulmonaria was selected to assess changes in distribution in time (cf. PIŠŮT, 1971). This species is very conspicuous in size and morphology; thus it is assumed this lichen was collected more frequently than other species and more data (published records and specimens in herbaria) will be available for reconstruction of its former distribution (Fig. 2). The oldest data concerning Slovakia are from the end of the 18th century, for territory of Bohemia from early 19th century. The majority of data originates from the end of the 19th century and first third of 20th century. Lobaria pulmonaria was formerly common in all mountain regions of Czechoslovakia (totally in 130 grid squares). Nevertheless, from the end of the nineteenth century its decline was recorded by various authors (ZAHLEBRUCKNER, 1894; LOS, 1928; Anders, 1935). Interesting there are data of last records of this lichen in mountains of western part of Czechoslovakia in which is now extinct:

1917 - Krušné hory	1954 - Orlické hory
1929 - Český les, Křivoklátsko, Hřebyny a Brdy	1955 - Beskydy
1942 - Krkonoše	1957 - Českomoravská vrchovina

There is a correspondence of this chronological sequence with a degree of deterioration of these regions. Likewise it is interesting that from the most polluted Krušné hory mountains sparse data are even from the oldest period. In central Bohemia, Lobaria pulmonaria vanished in thirties.

Similar enumeration of the last records in mountains of Slovakia is following:

1937 - Kremnické vrchy	1967 - Vihorlat
1938 - Malé Karpaty	1970 - Štiavnické vrchy
1959 - Slovenský raj	1983 - Belianske Tatry

(in both last mentioned mountains was found only one damaged thallus). In vicinity of Bratislava L. pulmonaria vanished in thirties.

Characteristic for decline of L. pulmonaria is decreasing of quantity, vanishing in low altitudes and surviving in protected habitats in the evergrowing altitudes. The old pre 1970 records are from 130 grid squares totally. At present, L. pulmonaria grows in western part of Czechoslovakia (Fig. 2) only in 4 grid squares (in all cases thalli are damaged). In Slovakia, L. pulmonaria is present in 17 grid squares; almost in all cases are visible symptoms of damage.

Similar decrease can be demonstrated on distribution of other pollution sensitive species, e. g. Ramalina fraxinea and Parmelia revoluta. Last mentioned lichen is extinct species of the Czechoslovak flora at present.

There is an interesting ecological group of lichens increasing in polluted areas. This phenomenon is probably caused by a certain degree of resistance to sulphur dioxide pollution, elimination of pollution sensitive species which would have had to compete, and an acidification of environment which favours this group of acidiphilous lichens.

Typical example of increasing lichen is Lecanora conizaeoides. Arise of this lichen is well documented in Britain from the end of the nineteenth century (HAWKSWORTH et al., 1973; LAUNDON, 1973); its spreading continues over whole Europe far to the east (cf. LIŠKA, PIŠŮT, 1987). Lichen L. conizaeoides is now one of the most common lichen in Central Europe; in many polluted areas is often only one lichen on tree bark. Another species with similar trend in changing distribution is Scoliciosporum chlorococcum.

Another use of data set obtained by mapping of lichens is an evaluation of any area from bioindication point of view. Each grid square we can evaluate on the basis of quantity (number of recorded species and quality (bioindication value of each species)). An example of such bioindication on a large scale is an evaluation of study area in central Bohemia.

To get objective picture of investigated area we have to view it in the broad context, i. e. to assess larger area (Fig. 3). The total number of epiphytic lichens gives rough image of real situation (Fig. 5). However, all species have not same value of bioindication. If we use distribution maps of selected bioindicators (i. e. qualitative scale), we get picture of air pollution gradient in the landscape (Fig. 4).

As it was shown, the total number of species can be good guide. To increase its value we excluded toxilitolerant species, species of wide ecological amplitude, species with possibility of subjective error (e. g. inconspicuous lichens which can be overlooked); in other words, we used total number of good indicator species only (Fig. 5). If we compare results based on these different characteristics, the last mentioned approach provides good method not only for the evaluation of epiphytic lichen flora, but also for the evaluation of air pollution impact. An occurrence of epiphytic lichens is besides air pollution affected by further factors: occurrence of suitable phorophytes, occurrence of woods and forests as well as landscape morphology affecting dispersion of air pollution, air humidity, altitude etc. Mapping of epiphytic lichens is thus possible to use for the landscape evaluation.

It was demonstrated that grid mapping of lichens gains valuable results which can be employed for various purposes. Further, it provides base-line of monitoring, against future changes can be assessed.

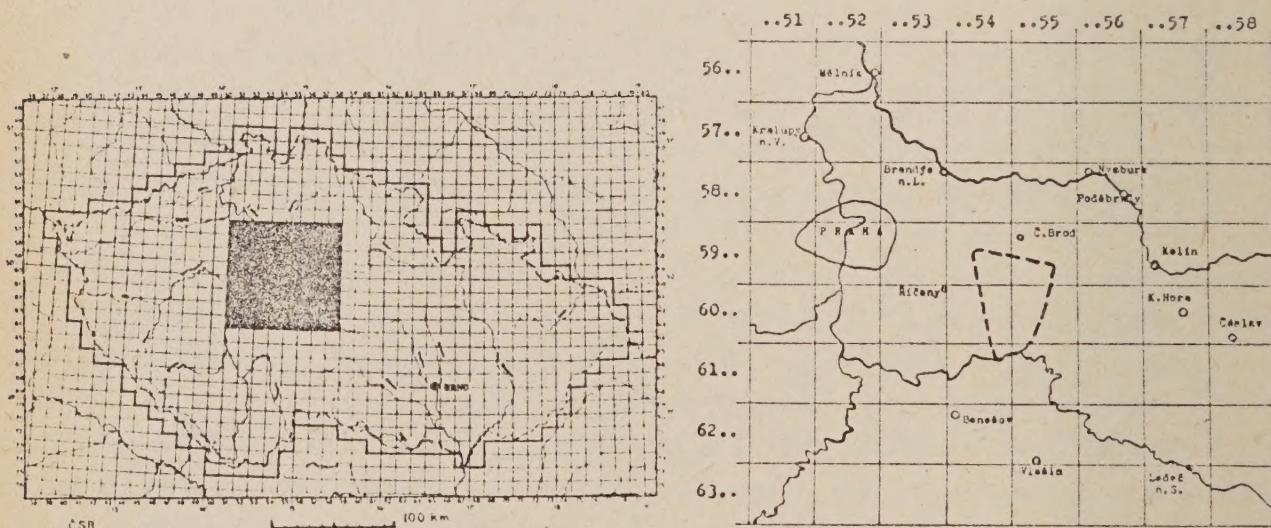
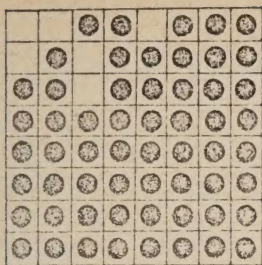
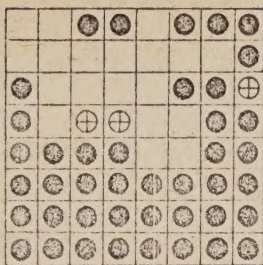


Fig. 3. Area of central Bohemia under investigation. The dashed line shows area of detailed monitoring.

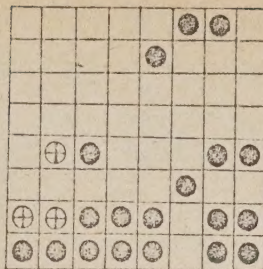
Hypogymnia physodes



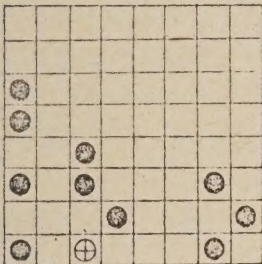
Parmelia sulcata



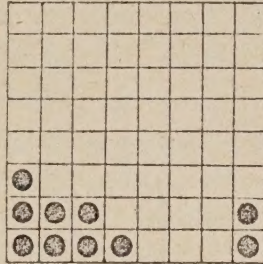
Evernia prunastri



Usnea hirta



Lecanora varia



Romalina farinacea

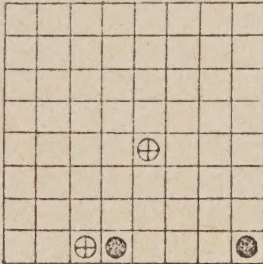
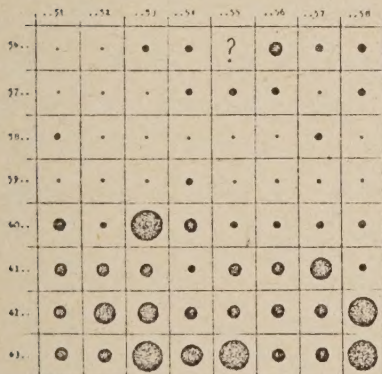


Fig. 4. Distribution maps of some indicator species (open circle with cross represents damaged thallus).

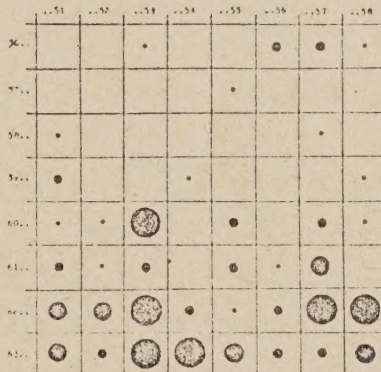
Numbers of epiphytic lichen species in grid squares
(richness of epiphytic lichen flora evaluation)



• 1 - 10 • 18 - 24 • >31
• 11 - 17 • 25 - 30

Numbers of selected bioindicator species in grid squares
(air pollution impact and landscape quality evaluation)

Bioindicators: *Bryoria fuscescens*, *Candelaria concolor*,
Cetraria chlorophylla, *Evernia prunastri*,
Hypogymnia tubulosa, *Lecanora varia*, *Parmelia*
acetabulum, *P. caperata*, *P. subrudecta*,
P. tiliaea, *Pertusaria albescentia*, *P. omara*,
Physcia stellaria, *Physconia pulverulacea*,
Platismatia glauca, *Pseudevernia furfuracea*,
Romalina farinacea, *R. fastigiata*, *R. fraxinea*,
R. pollinaria, *Usnea cf. hirta*, *Xanthoria polycarpa*.



• 1 - 2 • 6 - 8
• 3 - 5 • >9

Fig. 5. Summary results of mapping study in central Bohemia.

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Anthropogenic change of forest biocenoses assessed on space photographs obtained from subsatellite experiments

A. M. STEPANOV, T. V. CHERNENKOVA, O. B. BUTUSOV

A large bank of space photographs obtained from general-purpose resource and weather satellites ("Meteor", "Landstat") has been accumulated in the world. These photographs cover vast areas of the earth surface and have a low spatial resolution (70 -100 m). The information contained in them remains virtually unused, since little more than 1 % of the photographs has been interpreted so far, which is primarily due to the lack of reliable criteria for interpretation.

As for the refinement of contours or, generally speaking, any kind of the lineament treatment, the quality and reliability of the interpretation can be markedly improved by making use of multi-zonal satellite information in different spectral zones as well as by introducing complex spectral criteria (KONDRATYEV, 1981).

Far more tempting and valuable, however, are the attempts to use the spectral brightness (or the relative blackening) of space photographs for gaining information about the inner structure of natural ecosystems and the state of the natural cover of biocenoses, which is one of the main objectives of the background monitoring and monitoring in general. The problem cannot be solved solely through the development and improvement of purely external criteria, but rather requires investigation on the surface ecosystems, with the interpretation criteria being developed in the course of synchronous subsatellite experiments.

It should be noted that the requirement for synchronism is not too stringent, and it is quite possible to find information in the space data bank corresponding to the week during which the subsatellite experiments are performed and the state of biocenoses changes insignificantly.

In investigating the state of the ecosystems of southern taiga situated in both background regions and zones of anthropogenic action we aimed at establishing the representative "face" parameters of forest biocenoses, which could not only be accurately measured but also put in the one-to-one correspondence with the spectral brightness of space images, which is the common objective of subsatellite experiments.

In doing so we proceeded from the obvious consideration that the forest phytocenosis in a good state, with a large overground biomass and fully developed vertical (story) structure of plant communities must absorb incident light best, thus corresponding to the zones of maximal blackening on the space images, and vice versa, the most disturbed phytocenosis having large albedo must correspond to the brightest zones.

Another obvious consideration is that the images of forest phytocenoses subjected to anthropogenic action of various degrees from the maximum to the minimum must be available on the same image not far from each other. This would automatically eliminate the errors of interpretation and make it possible to obtain a complete optical wedge of spectral brightnesses. Therefore, an isolated factory immersed into the background environment and registered on a space photograph as a lumped (point) source of industrial effluents must be chosen as the object. In this case, the farther the territory from the source, the smaller the degree of anthropogenic disturbance of phytocenoses.

Fig. 1 shows a map of the region under investigation (the South Urals) with the location of the test areas. Fig. 3A presents a space image of this territory obtained from the "Meteor" artificial satellite with the use of "Fragment" equipment. Fig. 2 and 3B show the same image following computer processing. The spectral region of $0.7 - 0.8 \mu\text{m}$ was chosen as the most representative one for forest phytocenoses (PETRAKOVSKY et al., 1979). The source in the images looks like a rectangle-shaped black spot (a pond near the source) against a light background. The center of the affected zone is shifted to the East and South-East from the source of effluents in the direction of the prevailing wind and is located on the slopes of the neighbouring elevation (a series of white spots on Fig. 2). Comparing the parameters of forest phytocenoses measures on the test areas is, naturally, possible and correct only when dealing with rigorously identical phytocenoses. In the region under investigation we chose the mesophyte variant of frassy-motley grass birch groves, which presently prevail on the territories previously occupied by forest-steppe pine forest on grey forest soils. A requirement for the identity of phytocenoses is rather stringent. In choosing test areas account was taken of the exposure and grade of the slope, its location in the mesorelief, moisture content, soil type, composition of the plant community, age of the stand, and some other parameters. The natural requirement is that the measurements be completed in the shortest phenological period (as short as a week).

Tab. 1 presents the parameters determined. The areas located outside the zone affected by waste gases of the factory (30 km to the N. W., in the direction opposite to the prevailing bearing of apparent wind) were taken as control. However, owing to former fellings and fires no stand completely meeting the requirements could be found in this region nor on the areas located 5 km to the N. W. and 8 km to the S. E. The center of the affected zone is almost completely bleak. All the parameters there are equal to zero.

The stock of the stand was taken on test areas, 25 x 25 m in size. The parameters of the grassy-lowbush story were taken on a number of small test grounds ranging from 0.0625 to 1 m^2 and laid within the main test area with regard for the peculiarities of the horizontal, parcellar-sinusial structure of the oversoil cover. In evaluating species diversity the arboreous

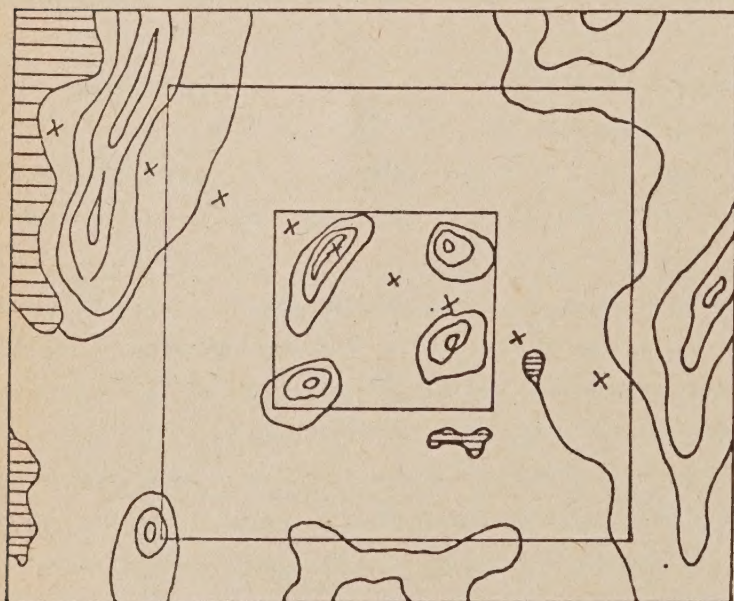


Fig. 1. Map of the region under investigation with the location of test areas.

and grassy-lawbush stories were united. The table shows litter to accumulate toward the source of pollution. As shown by others (KONOREVA, 1983) and confirmed by our data, decomposition of plant residues on the polluted areas is substantially retarded.

As a result we get a set of parameters correlated to a various degree with each other and with the elements of the space image. Each of these diagnostic parameters has its specific distribution area, the dependence on the degree of pollution, absolute value, and unit of measurement. Each of them reflects the degradation of a particular phytocenosis component in one or another specific form.

The main conclusion is that the statistical sum of all the parameters investigated is the most representative ("face") parameter. To sum up heterogeneous parameters, the values obtained are expressed as a percentage of the corresponding value for the control area (see Tab. 1).

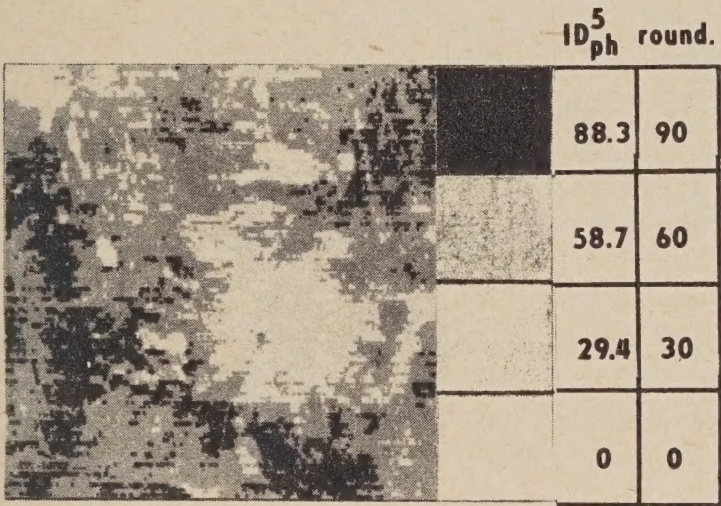


Fig. 2. Calibration of a space image subjected to 4-level quantization.

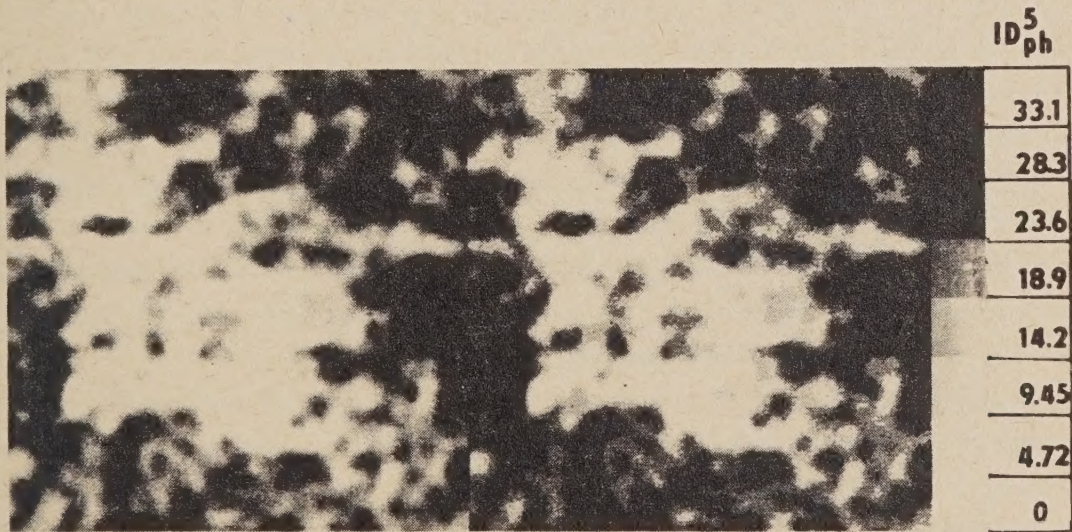


Fig. 3. Calibration of a space image subjected to 8-level quantization. A - original space image, B - processed and quantized image; the image is calibrated against the points 2 km to the N. W. ($ID_{ph}^5 = 18.1\%$) and 2 km to the S. E. ($ID_{ph}^5 = 19.7\%$), $(18.1 + 19.7)/2 = 18.9$.

Tab. 1. Diagnostic parameters of phytocenoses degradation (motley grass birch groves of the S. Urals).

Parameter	distance from the center, km	North-West				center		South-East			
		30	12	8	5	2	0	2	5	8	12
Number of trees per 625 m ²	-	27	22	-	-	106	0	39	43	-	53
Mean diameter (cm)	-	30.6	21.0	-	-	8.0	0	16.0	15.8	-	14.5
Cross-section area (cm ²)	-	735.0	346.0	-	-	50.2	0	201.0	196.0	-	174.5
Total cross-section area (cm ² x 10 ³)	-	19.84	7.63	-	-	5.32	0	7.84	8.43	-	9.24
Total cross-section area (%)	-	100	38.4	-	-	26.8	0	39.5	42.5	-	46.5
Phytomass (g/m ²)	90.6	90.0	52.0	25.1	0.43	0	3.2	10.8	33.8	70.8	
Phytomass (%)	100	99	57.4	27.7	0.47	0	3.5	11.9	37.3	78.1	
Projective coating (%)	92.8	56.5	62.0	31.4	2.4	0	3.3	18.0	32.5	75.0	
Projective coating (%%)	100	60.9	66.8	33.8	2.6	0	3.5	19.4	35.0	80.8	
Number of species	58	41	40	39	10	0	8	18	39	45	
Number of species (%)	100	70.7	69	67.2	17.2	0	13.8	31.0	67.2	77.6	
Litter mass (g/m ²)	630	568	664	804	1450	0	1659	1120	828	1072	
Litter mass (%)	100	110.9	94.9	78.3	43.4	0	38.0	56.2	76.1	58.8	
10 ⁵ _{ph} (%)	100	88.3	64.3	51.6	18.1	0	19.7	32.2	53.9	68.4	

The litter masses are taken as inverse values whose ratio characterizes the efficiency of litter decomposition.

Thus, we have a matrix expression:

$$10_{ph}^k = \frac{1}{n} \sum_{i=1}^n \frac{A_{ij}}{A_i} \tag{1}$$

where A_{ij} are the values of the i -th degradation parameter, A_i is the control value of the i -th parameter, and j is the number of the test area. Summing these values over the columns followed by averaging gives the meanings of a complex "phytocenosis degradation index" - 10_{ph}^k . The superscript figure stands for the number of the parameters involved.

The 10_{ph}^5 values of 18.1 and 19.7 presented in the table correspond to the points 2 km to the N. W. and 2 km to the S. E., respectively, located in the dead-cover birchgroves, the last stage of existence of forest vegetation in the vicinity of factory. Of all the components of the phytocenosis pre-existed there as motley grass pine forests, the only arboreous story has remained, represented by birches resistant to chemical pollution. Only rare groups of cereals (reedgrass, couch-grass) are present in the grass cover. Most soil is exposed, the litter is washed down from the slopes and accumulates in depressions as undecomposed mass of slump consisting of birch branches and leaves.

The original space image was subjected to preliminary processing by the following algorithms for 4- and 8-level quantization and for improving the contrast range.

The contrast range improvement algorithm is:

$$I(m) = \frac{(i(m) - i_{min})(I_{max} - I_{min})}{i_{max} - i_{min}} \tag{2}$$

where $i(m)$ and $I(m)$ are the original and transformed brightnesses of the point m ; $i_{\min}$, $i_{\max}$, $I_{\min}$, $I_{\max}$ are the minimum and maximum brightnesses of the original and transformed image.

The quantization algorithm is:

$$m \in B_i \text{ if } Q_i \leq P(m) < Q_{i+1} \quad (3)$$

Here, $\{B_i\}$ is the system of classes of the quantized image, Q_i are the selected brightness levels, $P(m)$ is the brightness of the point m (the diagnostic indication).

The resulting computer-transformed image is presented in Fig. 2 and 3B. Brightness exceeding a predetermined level was assumed as the diagnostic indication.

Further separation of areas on the image was performed by a specialized dialogue contouring algorithm based on the base contours method (PETROV, et al., 1981). Base contours were taken as rectangles and used for separation of inner and outer regions of the objects to be contoured in the dialogue processing regime. For the separated areas mean brightnesses and variances were determined. The elements between the base contours were processed in order to find boundary elements. The processing was carried out in two steps. The first one involved comparing the characteristics of brightness elements with the corresponding values for the inner and outer zone of the area to be separated. This made it possible to determine zones, to which the elements belonged. The criterion used had the form:

$$\begin{aligned} m \in A \text{ if } I_A - \sigma_A - (I_i + \sigma_i) &< I_i - \sigma_i - (I_B + \sigma_B) \\ m \in B \text{ if } I_A - \sigma_A - (I_i + \sigma_i) &< I_i - \sigma_i - (I_D + \sigma_D) \end{aligned} \quad (4)$$

where I_i and σ_i are parameters of the brightness element, A is the class of inner elements, I_A and I_D are the mean brightnesses of the corresponding zones, σ_A and σ_B are brightness variances in the corresponding zones. The second step involved determining the number of elements of the both classes adjacent to each brightness element located between the base contours. The final requirement for the element to be considered as a boundary one was that

$$|n_A - n_B| \leq 1 \quad (5)$$

where n_A and n_B are the numbers of the adjacent class A and B elements, respectively.

The boundary obtained is narrow enough, but irregular, obscured by noise. To eliminate such an irregularity the boundary was subjected to generalization. A special algorithm has been developed, which permits the separated areas to be approximated by means of polygonal formalizations. The algorithm generalizes the irregular boundary of the natural object in such a way that the resulting formalization retains all the significant properties of the object, simplification being achieved at the expense of minor, insignificant details reflecting the effect of interferences and small-scale features of the contour. The degree of generalization is given by a single manipulated variable. The formalizations thus obtained are insensitive to the noisiness of the object boundaries, thus allowing the images of the same object with different degrees of noisiness to be approximated in the same formalized way. The latter circumstance permits the comparison with the standard in interpreting the formalization obtained to be made in terms of quantization of images rather than quantization of the decision function (ANISIMOV et al., 1983). This allows one to simplify the corresponding recognition algorithms.

It is to be noted that this operation is invariant under such transformations, and the algorithm should, therefore, use similar polygons for contouring the images of the same object obtained on a different scale. This is important for the comparison of formalizations obtained through the interpretation of images with different magnitude of the noise component with standards from data bank.

Formation of other sides of the formalization is accomplished in a similar way, the path being traced around several times until the following condition is satisfied:

$$\|r_0 - r_N\| < \varepsilon \quad (6)$$

where r_0 and r_N are the starting and terminal points of the formalization, respectively, and ε is the predetermined accuracy of approximation. This makes the approximation form independent of the starting point location. The means of formalization described gives a system of uniformly formalized landscape elements, which makes the interpretation of space images and identification of uniform phytocenoses more convenient.

Fig. 2 presents an example of calibration of a space image subjected to computer processing and 4-level quantization. The image is calibrated against the point 12 km to the N. W. with the phytocenosis degradation index (ID_{ph}^5) of 88.3%, which corresponds to the darkest level on the image (Fig. 2).

The image in Fig. 3B is calibrated against the points 2 km to the N. W. (and 2 km to the S. E).

The correlation established is accurate within a quantization step for all the phytocenoses studied. This suggests that space information can be used for determining the degree of degradation of forest ecosystems in similar cases. The following sequence of diagnostic operations could be proposed for this purpose. The first step involves localization of the source of anthropogenic action and basic landscape elements. Then uniform phytocenoses are selected with the help of geobotanical maps. Their images on space photographs are contoured (for instance, by means of the above described base contour algorithm), generalized, and placed in correspondence with the contours on the geobotanical map. Finally, complex phytocenosis degradation indices are determined from the calibration table.

The spatial accuracy of the method can be estimated by studying the shift of the contours resulting from a change of the quantization step.

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The assessment of the ecological effects of soil pollution by chemicals

C. A. EDWARDS

INTRODUCTION

There is a vast scientific literature on the effects of pollution of air, freshwater and the oceans by toxic chemicals. The conclusions reached from these studies, although sometimes controversial, are reasonably consistent. However, the scientific literature on the effects of pollution of soil on the biological functioning of soil systems is much more scattered, varied and inconsistent. To a large extent this is because we know much less about the functioning of soil systems than of aquatic ones, but also because it is much more difficult to establish the degree of contamination of land by such chemicals and the need for complex sampling techniques and extensive surveys to establish the effects of chemicals. Many kinds of chemicals can affect soil ecosystems, but the ones that tend to have long-term effects are relatively persistent in soils.

Historically, contamination of soil by toxic chemicals dates back to the use of inorganic pesticides such as copper sulphate, introduced as a fungicide in 1892, lead arsenate first used as an insecticide in 1892, the arsenical herbicides produced in 1900, the organic mercurial fungicides in 1913, and copper silicate in 1936. All of these pesticides, which are based on heavy metals, tend to persist so much that some orchard soils have become very heavily contaminated due to treatments over many years. Other relatively persistent chemicals with potentially toxic effects on soil organisms are the organochlorine insecticides, the first of which was DDT introduced in 1939, BHC in 1942, chlordane in 1945 and others from 1948 onwards. Most soil contamination by such chemicals resulted from application to agricultural and horticultural land.

More recently, contamination of natural environments has occurred by the aerial drift of pesticidal spray particles or dusts or by the volatilization of pesticides into the atmosphere, (from where they may be washed out in precipitation and fall on the soil). Additionally, chemicals emitted from industrial factories e.g. brick or smelting works such as sulphur dioxide, and the lead given off from car exhausts can be washed out of the atmosphere and contaminate nearby land. Finally, the increasingly common practice of depositing processed human sewage that contains many contaminants, especially heavy metals, on to agricultural land has led to wide-spread pollution of some soils. Fields that have been treated regularly in this way since before the Second World War, may contain very large amounts of certain heavy metals, which can be transmitted into crops grown on them.

The assessment of the effects of chemicals on soil systems is difficult. Firstly, the extent, nature, and amount of contamination has to be assessed. This can be done by surveys involving extensive sampling, followed by residue analyses. Such surveys, on local, national, or international levels, are extremely expensive in terms of both resources and manpower and because of this there have been relatively few large scale surveys to date. Once a suitable sampling programme has been designed, the only major problem in assessing the degree

of contamination by residue analyses is the resources required, because analytical methods for most pesticides and heavy metals are available since most government registration authorities insist that suitable chemical methodology is available before they will register a toxic chemical for general use.

Such surveys do no more than establish the degree and distribution of soil contamination by toxic chemicals. The assessment of the overall effects of chemical contaminants on populations of soil organisms and on dynamic soil processes raises many more problems. It is not difficult to devise laboratory bioassay techniques which will indicate the toxicity of different chemicals to certain readily identifiable soil organisms, but it is much harder to interpret such toxicological data in meaningful ecological terms. Even more complex, is the design of experiments which can assess accurately the effects of toxic chemicals on the total fauna and flora of the soil (EDWARDS, THOMPSON, 1973). Such studies are very laborious and time-consuming and require not only a thorough taxonomic knowledge of such organisms, but also the availability of efficient methods of adequately sampling populations. For general purposes, the usual approach is to assess the effects of the chemicals on a range of dominant, representative and important indicator species in carefully replicated field experiments. These experiments are sampled periodically after the test chemicals have been applied and populations of organisms in them are assessed by methods that have been fully summarized elsewhere (EDWARDS, FLETCHER, 1970).

There are methods of investigating the broader impact of toxic chemicals on soil systems: these involve studying the effects of chemicals on soil metabolic processes, such as organic matter breakdown, soil respiration or mineralization of nitrogen, phosphorus and possibly sulphur. Such studies, made in the laboratory or field, can give a much better general idea of the important effects of toxic chemicals on key soil processes (EDWARDS, 1979).

THE CURRENT SITUATION IN ASSESSING THE EFFECTS OF CHEMICALS ON SOIL ORGANISMS AND ECOSYSTEMS

The literature on the effects of chemicals on soil organisms and soil processes is voluminous. Moreover, it is extremely diverse, ranging from reports of the effects of chemicals on individual species of organisms, to those on populations and on dynamic soil processes, using a great diversity of methods in both field and laboratory. Many of the laboratory experiments reported in the literature have been done in vitro, or involve unrealistic doses of chemicals, methods of application, and modes of exposure, and it is virtually impossible to compare the results of experiments by different workers using the same chemical and reach a valid conclusion. Field experiments have been even more varied often lacking controls and with unrealistic methods of application and doses.

There have been a number of reviews on the effects of chemicals on soil organisms but these have addressed either effects on the soil fauna (d'AGUILAR, 1956; DRIFT, 1963; EDWARDS, 1970; EDWARDS, THOMPSON, 1973; THOMPSON, EDWARDS, 1974; EIJSACKERS, DRIFT, 1976; EIJSACKERS, BUND, 1980) or effects on the soil microflora (ANNON, 1976; GREAVES et al., 1978; GROSSBARD, 1976; ANDERSON, 1978; MCCANN, CULLINONE, 1979; SIMON-SYLVESTRE, FOURNIER, 1979; DOMSCH et al., 1983) independently. Such approaches reflect a disciplinary approach to ecotoxicological research, which seldom addresses the effects of chemicals on interactive processes that involve both

the soil fauna and microflora and are fundamental to soil fertility and productivity. Only one review published to date has considered the overall effects of chemicals on whole soil ecosystems or even on both the soil fauna and microflora, with the aim of determining any common basis for evaluating environmental hazards caused by chemicals that reach soil (EDWARDS, 1988).

In this paper, I propose to describe some of the failings in experimental techniques and then review the methods available for assessing effects of chemicals on soil organisms and processes, and recommend methodologies involving key species and processes that might be used as indicators of environmental hazards resulting from chemicals which reach soils.

Many field experiments have been designed poorly; for instance, seven per cent of those reviewed had no controls of any sort (LOFS-HOLMIN, BOSTROM, 1988). Even those that compared any effects of chemicals with those in control areas often involved different sites where the soil type and spectrum of organisms would be quite different from those in the treated area. Some workers used samples as controls taken days or weeks before treatments were applied. Another major failing with field experiments has been poor replication. Many field experiments involved no replication of treatments or reported the replication inadequately. Many experimenters did not report the dose of chemical used adequately (23 %), or in terms that can be related to other experiments. Less than one-quarter of experiments provided adequate data on soil type, organic matter and clay content, pH, nutrient status, and physical characteristics.

Laboratory experiments reported in the literature suffered from even more variability and often had less relevance to valid assessment of the environmental impact of chemicals. Even more of the laboratory experiments (14 %) lacked effective control treatments. Many did not use truly appropriate controls, such as applying a solvent to the controls when the test chemical is applied to treated units in such a solvent. In laboratory experiments, the method by which the test chemical was applied often bore little relation to the way in which the chemical would reach the soil or organism in the field. Such application techniques cause problems of relating the experimental dose used to concentrations that would impact upon organisms or soils in the field. In many experiments (23 %) it was not possible to determine the dose used from the data reported.

When laboratory experiments have used soil as the test medium, there was been little attempt to standardize or even describe the soil type used for the tests. In the great majority of experiments, no information at all on soil type was given. Very few workers defined the environmental conditions under which their test assays were made; indeed only 65 % defined the temperature used.

In tests using soil-inhabiting invertebrates, few described the source of their test organisms or breeding techniques; many were collected from the field where they may have been contaminated or have developed resistance to chemicals prior to the experiment. In tests using single species of microorganisms, the chemicals were often applied to petri-dish cultures in media such as agar gel.

Thus, in general, the methodology used in terrestrial ecotoxicology can be seriously faulted. There are almost as many experimental methods described as there have been scientific papers. However, more recently, international organizations such as the Organization for Economic Cooperation and Development (OECD), The European Community (EEC), and the Food and Agriculture

Organization of the United Nations (FAO) have attempted to promote the use of more standardized testing methodologies, both in terms of "key indicator organisms" and "key soil processes". (EDWARDS, 1983, 1984).

METHODS OF ASSESSING EFFECTS OF CHEMICALS ON SOIL INVERTEBRATES

Soil-inhabiting invertebrates differ greatly in form, size, numbers, function, life styles, spatial distribution in soil, seasonal abundance and sensitivity to chemicals. They may be of pests of plants, predators or parasites of plant pests or play an important role in the degradation of organic matter in soil and recycling of nutrients.

Laboratory Assays

For laboratory tests, it is essential to use test organisms cultured in the laboratory with no previous history of exposure to the test chemical or related compounds. However, many organisms cannot be cultured satisfactorily in the laboratory and there are serious disadvantages to using field-collected organisms of unknown history. Further problems exist in the availability of efficient methods of extraction, separation or culture of the organisms from soil, maintenance in the laboratory and seasonal availability. Moreover, large numbers of test organisms that are physiologically and genetically uniform are required for laboratory tests. Hence, most laboratory studies concentrate on those species of organisms that are easily bred, with simple food requirements, adapted to surviving in dense populations, and with a rapid rate of reproduction. However, if these organisms are not typically sensitive to chemical, or play an important role in soil processes, they should not be used.

In all laboratory experiments, it is essential that the experimental test conditions be defined and controlled precisely and related closely to conditions under which the test organisms would be exposed to a chemical in the field. This may involve relatively complex laboratory test conditions e.g. a fluctuating temperature regime. In all laboratory experiments, the design of the test, the test conditions, the dose and other factors should relate realistically to exposure in the field. It must be decided prior to any experiment whether the aim is to assess environmental hazard to the chemical under "average" or "natural" environmental conditions or under extreme conditions where effects may be more catastrophic.

Representatives of many of the major groups of soil-inhabiting invertebrates have been used in laboratory testing methods. To act as a good indicator species they should:

- play an important role in soil ecological systems
- be common in a broad range of soils and geographical areas
- be moderately sensitive to a wide range of chemicals
- make a significant contribution to total soil biomass
- be active and move actively through soil to ensure that they come into contact with chemicals (EDWARDS, 1987).

Additionally, they should be able to be cultured relatively easily.

The methods of exposure of the test organism is important. Methods used include:

- injection of a test chemical into the body of the organism (STRINGER, WRIGHT, 1976)

- topical application of a test chemical to the organism's body (EDWARDS, 1973)
- exposure to the chemical on a treated surface such as glass (TAYLOR, 1982) or filter paper (EDWARDS, 1983)

All of these methods can be used for screening or ranking the toxicity of chemicals, but results of such assays are virtually impossible to evaluate in terms of to these chemicals.

Another test involves assessing the effects of chemicals on soil-inhabiting invertebrates, when they are ingested with their food. This is done by treating plant material or artificial diets with the herbicide, then feeding it to test animals. The amount of food offered to test animals must relate to amounts they would consume under natural conditions. Such experiments are very difficult to do and to interpret, and the results are usually very variable.

More realistic is the exposure of test organisms to soil treated with the test chemical. The chemical can be applied to soil by spraying or mixing, after which the test animals are kept in the treated soil for a defined period before assessing extent of mortality. A wide range of soil types have been used for such tests. Since different chemicals become absorbed onto organic matter and clay fractions in soils, and often become bound in a non-toxic form (EDWARDS, 1966), the toxicity of any chemical to a test species differs widely with the soil type to which the chemical is applied. One solution to this problem was provided by EDWARDS (1983) who prepared a standardized artificial soil, consisting of 69 % sand, 20 % kaolinite clay, 10 % sphagnum peat and 1 % calcium carbonate and used this for the assay. This enables chemicals to be tested for toxicity to soil organisms in a much more standardized manner.

The standard assessment that is always made is the acute toxicity of a chemical to test organism, although many different criteria have been used to ascertain the death point. The commonest measurements used to report toxicity data are the median lethal dose (L.D.₅₀), median lethal concentration (L.C.₅₀) or the median lethal time (L.T.₅₀).

Studies on the effects of chemicals on soil organisms can also involve assessment of chronic toxicity and other effects of chemicals. The effects of chemicals on reproduction, numbers of eggs, cysts or cocoons produced by invertebrates have all been used as indicators of chronic toxicity. Some workers have used weight gain of test organisms as an index (EIJSSACKERS, 1978; LOFG-HOLMIN, 1980). In a few experiments, the moulting rate of arthropods has been used as a criterium by counting cast skins or exuviae (EIJSSACKERS, 1978; LOFG-HOLMIN, 1980). Rates of feeding have also been used as evidence of chronic toxicity (EIJSSACKERS, BUND, 1980). In all laboratory tests, careful records of the environmental factors are essential to ensure reproducibility of the results.

Field Experiments

The exposure of whole soil ecosystems to chemicals in the field is an attractive method of assessing the overall effect of the chemical. However, the results of assessments of toxicity from field experiments are extremely variable and depend on soil type, soil structure, degree of cultivation, amount of organic matter in the soil, and climatic conditions. It is essential that the effects of chemicals on populations of soil organisms be compared with those in a standard untreated area, i.e. a control, and that the treatments and controls are replicated adequately. The size of plot need not be large but must be related inversely to the size of the largest invertebrates being sampled. Fortunately, truly soil-inhabiting (edaphic)

invertebrates do not migrate very far laterally through soil, so plots about 10 mm square are adequate for experimental assessments of the effects of chemicals on most groups of soil-inhabiting invertebrates. However, surface-living (semi-edaphic) invertebrates, such as carabid and staphylinid beetles can travel large distances over the soil surface and need plots of at least 0.5 ha, or surrounded by barriers, to prevent lateral movement of these animals between treated and untreated plots.

Because of the great diversity amongst soil-inhabiting invertebrates and their wide range in size, numbers and habits, different sizes of samples and methods of separation of invertebrates from soil are necessary for assessing populations of different invertebrates. Soil samples can be taken with corers or augers which range in diameter from 2.5 cm to 20 cm. Most soil inhabiting invertebrates live in the top 10 cm of soil, so samples taken in a vertical depth of 10 - 15 cm can recover up to 80 % of the total populations.

Most species of arthropods can be extracted from soil in modified high gradient Tullgren samples (EDWARDS, FLETCHER, 1973) or by flotation methods based on that developed by SALT and HOLLIICK (1944). Nematodes can be extracted from soil in Baermann funnels (BAERMANN, 1917) or by elutriation techniques (SEINHORST, 1962). Earthworm populations can be sampled in the field by pouring dilute formaldehyde (50 ml in 9 litres) on to the soil surface in defined quadrats. This stimulates the worms to emerge to the soil surface where they can be collected and counted (RAW, 1959).

Populations of many soil-inhabiting invertebrates can be sampled by inserting pitfall traps into the soil, flush with the soil surface, and collecting animals that fall in to the trap. Traps may be dry or contain liquids such as ethylene glycol, formaldehyde or glycerol. A drawback to using pitfall traps is that they measure both invertebrate populations and activity, and it is difficult to relate trap catches to actual populations per unit area. However, since they assess functional activity as well as populations, they can provide a useful index.

For an overall assessment of side-effects of chemicals on invertebrates a judicious set of complementary laboratory and field experiments are probably the most effective combination. The laboratory experiments can assess quickly the effects of a range of doses of different chemicals. They can also identify those environmental conditions which can cause the greatest effects and allow an extensive screening of chemicals to be made, so that those organisms most susceptible to chemicals can be identified and most attention given to them in the field experiments. Field experiments can assess the effects of longer-term exposure to herbicides in soils under natural and climatic conditions and recommended doses.

It is important to ensure that in both field or laboratory experiments, the test organisms and soils should not have been exposed previously to the chemical under test to eliminate any possibility of soil organisms having developed resistance to specific herbicides, either directly or through cross-resistance.

METHODS OF ASSESSING THE EFFECTS OF CHEMICALS ON SOIL MICROORGANISMS

Populations of microorganisms in soil are extremely large. Bacteria are the most numerous soil microorganisms ranging from 10^6 to 10^9 bacteria per gram of soil. Numbers of actinomycetes range from 10^5 to 10^8 per gram of soil and fungi range from 10^4 to 10^7 per gram of soil.

This represents a biomass of 500 kg per ha of bacteria, 700 kg per ha actinomycetes and 1 000 - 1 500 kg per ha of fungi. They differ greatly in function, different groups being involved in such functions as organic matter breakdown, degradation of xenobiotics (including herbicides), nutrient cycling, pathogens of plants and pathogens of invertebrates.

Most soil microorganisms can be cultured on different kinds of growth media such as nutrient agar, and it is relatively easy to screen the effects of chemicals on microbes in this way. Unfortunately, such results are difficult to interpret because the way in which they are exposed to chemicals is so different to their exposure in nature that they are of little use in assessing the overall environmental effects of a chemical. However, such screening does identify those chemicals that have little or no inherent toxicity to microorganisms and is valuable in the interpretation of the results of field experiments better.

Chemicals can be applied to soil samples collected from the field, and the resulting effects assessed by counting populations of microorganisms in the samples, at periodic interval after treatment, and comparing them with populations in untreated control samples. However, such an assessment of whole populations of microorganisms is both difficult and time-consuming, even though it is possible to count microorganisms directly under a microscope using soil suspensions from treated soils. Such tests have the advantage of being carried out under ecological conditions which resemble those in the field; but when assessing the effects, it is difficult to distinguish between living microorganisms and dead ones, and dead organisms are not usually included in the characterization of the active populations in a soil. The use of fluorescence and of coloration techniques can, however, reduce such errors to a certain extent.

More usually, microorganisms are counted after they have been grown on suitable media, which are usually synthetic organic media, either liquid or soil (with gelose) or mineral (silicogel). Microorganisms are introduced from inoculum suspensions, more or less diluted with water, into the medium or on to its surface. After a period of incubation, the numbers of microorganisms are estimated from the count of the colonies on the plates or from an estimation of the highest dilution that permits the growth of the microorganisms. The number of microorganisms per gram of soil can be calculated on the basis of the observed growths. This method of determination may be used on soil samples taken directly in the field from treated experimental plots, or in trials carried out in vitro in a laboratory, or in a greenhouse. More usually, total microflora is counted in a soil aqueous extract (SIMON-SYLESTRE, 1974). Some workers add yeast and mineral salts to this medium.

Fungal populations can be counted after inoculation of a medium containing rose bengal that contains streptomycin, which impedes the growth of bacteria. However, some fungi are sensitive to streptomycin and cannot grow on media containing this antibiotic. Another suitable medium is a gelose medium.

Counts of bacteria are often made on a medium called nutritive gelose or on Czapek's gelose medium. Spore-forming bacteria can be separated from the others by heating the soil for 10 minutes at 90° C or by heating a soil suspension for 15 minutes at 75° C.

Actinomycetes can be counted on media containing antibiotics, e.g. nystatine and actidione or albamycine and streptomycin. Such plating methods can provide estimates of the total populations of the major groups of microorganisms in treated and control plots and samples.

However, dilution counts can lead to some errors; for instance, some criticisms may be exposed concerning methods of dilution counts: The number of microorganisms counted is always much lower than that read by direct numeration, by a factor of $10 - 1\ 000$, on the average, because certain organisms, such as anaerobic bacteria, autotrophic bacteria, and strictly cellulytic organisms, do not grow on media because their feeding requirements are too specific. In spite of standardization of techniques of dilution, inoculation and incubation, the precision of the measurements may be questionable due to difficulties of sampling and heterogeneity of soils. It is not possible to distinguish between inactive microorganisms and those very active in the soil. In fact, dilution methods often lead to the suppression of biostasis and synergism. Organisms with vegetative and reproductive forms may be cut into pieces and spores scattered, both of which can lead to errors in conclusions.

There are two types of techniques for determining total microbial activity: (I) Techniques which allow the activity of microorganisms to be characterized. The treated soil may then be used just as it is, as the basis of the analysis, or for seeding the media (grains of soil, suspension dilutions). (II) Techniques which determine the activity of the microflora by measurement of enzymatic activity.

METHODS OF ASSESSING THE EFFECTS OF CHEMICALS ON DYNAMIC SOIL PROCESSES

The soil biota, comprising the soil-inhabiting invertebrates and microorganisms, act together interactively in breaking down organic matter releasing mineral nutrients and incorporating these materials into the structure of the soil. This overall biological activity in soil is important in maintaining soil fertility and may be affected by pollutant chemicals. Thus, key processes and other biological cycles are the ones which may be vulnerable to chemicals that become introduced into soils.

Organic matter breakdown

The breakdown of organic matter seems to be the most important process occurring in soil since it is the major source of inorganic nutrients, and it should be a key technique in assessing hazards due to pesticides such as herbicides. Many methods of determining the effects of chemicals on organic matter decomposition exist, e.g. measurement of mineralization of organic matter under well-controlled conditions.

Another technique is to follow the degradation of organic matter, such as straw, after treatment with chemicals (MALKOMES, 1980). The straw is sprayed with the chemical, then placed in nylon mesh bags with 2 mm aperture mesh, and buried in soil to a depth of 3 cm. Decomposition is measured gravimetrically, on a sacrifice basis, and in soils with high organic matter content, losses in weight during ashing should be accounted for.

Other similar methods utilize uniform 5 cm disks of filter paper or of suitable tree leaves e.g. oak, beech, live elm or other suitable species. Fifty such disks are enclosed in a nylon mesh bag of 5 mm aperture mesh (EDWARDS, HEATH, 1963). A large batch of such bags are buried in soil to a depth of 5 cm and dug up at regular intervals. For assessment of breakdown due to invertebrates only, disks are washed and their surface area measured by light transmission,

after laying them out on a glass plate or moving translucent band. The amount of light passing through them is measured on a photoelectric cell and the data recorded. After measurement, disks are replaced in the bag and reburied. For assessment of overall microbial and invertebrate degradation sets of disks are ashed and measured gravimetrically as with the wheat straws.

Total soil respiration

Respiration measurements are probably the commonest methods of assessing microbial activity in soil, because respiration usually correlates well with other soil activities, such as transformations of carbon, phosphorous and nitrogen. The use of radioactive isotopes has alleviated many of the problems of non-specificity involved in traditional methods of measuring respiration. Measurement of total soil respiration (oxygen uptake and carbon dioxide evolution) can be made in a Warburg respirometer, after small soil samples are treated with a test chemical at appropriate doses. A specially designed large version of the Warburg apparatus (JENKINSON, POULSON, 1976) allows larger samples treated with pesticides to be measured (EDWARDS, 1983). Nutrients can be added to the soil to measure their metabolism. Typical nutrients used in this way include glucose and mannitol. These techniques are used in short-term experiments (2-3 weeks), but longer term measurements, the technique of sweeping soil samples with CO_2 -free air can be used. In its passage through the soil, the air becomes heavy with CO_2 from catabolic activities; it is then possible to trap and to titrate the CO_2 formed. For respiration measurements on soil which need to last for long periods, the preferred method is to incubate the soil under test in a flow of CO_2 -free air and to measure CO_2 production by titrimetry (GREAVES et al., 1978). Short-term measurements of CO_2 production or O_2 uptake often have little value in the general assessment of side-effects.

Measurement of oxygen uptake can also be made using electrolytic respirometers. The general principle of these are the incubation of soil samples in closed cells with periodic introduction of oxygen, by electrolysis, to compensate for the soil uptake (MacFADYEN, 1961). In order to work under more natural ecological conditions, some workers have made their activity measurements directly in situ in the field, in soil treated with chemicals as for instance by Dommergue's technique (1965).

One of the most serious criticisms of using respiration measurements to assess the effects of chemicals on soil respiration, whether by CO_2 production or O_2 uptake, is that a measured nil or small effect may hide large, counterbalancing, stimulation and inhibition of different major parts of the soil microflora. This criticism i.e. a toxic effect on respiration balanced by extra respiration resulting from utilization of the herbicide as a substrate, certainly leads to the conclusion that respiration measurements should be used only in conjunction with other methods of assessing more specific side-effects on microbial function.

Nitrogen transformations

Since mineral nitrogen is a major plant nutrient, there have been many studies on the effects of chemicals on the mineralization of soil nitrogen. Another reason for the popularity of such studies is because the chemical analytical methods for following nitrogen transformations, especially for measuring nitrate-, nitrite- and ammonium-nitrogen, are simple, sensitive, accurate, reproducible, readily automated and allow optimum replication (ANDERSON, 1978).

Ammonification and nitrification, as parts of the N-mineralization process, are the most useful systems for studying the side-effects of herbicides on nitrogen cycles. Ammonification is the indicator for the release of nitrogen bound in organic matter and its availability for plant nutrition. Nitrification, i.e. the oxidation of ammonium to nitrite and nitrate, is due to sensitive bacteria, and impairment of nitrification may be indicative of harmful influences of chemicals. The effects of chemicals on the release of ammonium from organic matter can be studied by addition of 0.5 % lucerne-meal to soil. If ammonification is not affected, the two steps of nitrification can be studied in the same experiment. If ammonification is inhibited, a separate experiment is required to study nitrification independently. This is achieved by adding ammonium sulphate (100 ppm N) to the soil and following the disappearance of NH_4 and the appearance of NO_2 and NO_3 . Studies of ammonification need to be followed until equilibrium is reached between ammonification and nitrification, but in any case not for less than 4 weeks. Studies of nitrification of ammonium sulphate are continued until either the added substrate has been converted or until an equilibrium has been reached between ammonification from soil organic matter and nitrification. Care must be taken, especially with clay soils, to avoid anoxia which might cause denitrification.

Many free-living microorganisms can fix atmospheric nitrogen and nitrogen-fixation by symbiotic organisms associated with legumes is of great importance. The susceptibility of Rhizobium spp. to chemicals has been investigated by a variety of methods, ranging from plate counts of Rhizobium cells to examination of nodulation of legumes (ANDERSON, 1978).

Tests aimed at assessing the effects of chemicals on nitrogen fixation depend upon the unique symbiotic relationship between the host plant and Rhizobium, and can determine in a single test both plant and bacterial responses to a herbicide. The following data are assessed: measurement of plant growth, plant yield and an estimate of healthy nodulation over time. These experiments can be made using plants in pots with soil treated with chemicals. If the chemical causes a critical effect in these tests, further data can be obtained on the direct effects of the pesticide on the Rhizobium organism, the nodulation process and the nitrogen-fixation (e.g. acetylene reduction) ability of the whole plant or intact root system.

There are problems in assaying the side-effects of chemical nitrogen fixation by legumes because large standard errors are often associated with the acetylene-reduction method and with measurements of nodule numbers and weights. Plant weights seem more satisfactory for assessing effects of herbicides on the legume. The most valuable information comes from measurement of plant growth rather than from more specialized measurements of Rhizobium populations or function.

C O N C L U S I O N S

The assessment of the effects of chemicals on soil organisms and dynamic soil processes is a very difficult problem due to the innate complexity and resilience of soil systems. In spite of the vast literature on the subject, overall conclusions on the hazards of particular chemicals are difficult to reach.

Preferably, to reach a balanced conclusion, data are needed from both the laboratory and field assessing the effects of chemicals on certain key indicator organisms which must include

both soil-inhabiting invertebrates and microorganisms. However, the most valuable data are those that relate the effects of chemicals on key soil processes that affect soil fertility and maintenance. The techniques used must be relevant to field conditions and mode of exposure. The experiments must use realistic doses, methods of application and test organisms and processes and be fully replicated. There is an urgent need for harmonization of test methodologies and methods of interpretation.

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The effect of industrial dust on the activity of soil microorganisms in the Niepołomice forest (southern Poland)

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The Niepołomice Forest, lying about 20 km southeast of Cracow, occupies an area of about 110 km² and is a complex composed chiefly of mixed pine forest and, to a lesser degree, of oak-hornbeams. For over 30 years it has been under the influence of industrial atmospheric pollution consisting of gases and dusts, mainly from the metallurgy plant of the Lenin Steelworks in Cracow, and the agglomeration itself.

The annual deposition of dust per km² of the area is about 100 t, that of sulphur (in SO₂ form) being about 6 t (GRODZINSKI et al., 1984).

In the southern part of the Niepołomice Forest, in a habitat of mixed pine forest growing on rather poor soils formed on pleistocene fluvioglacial sands (podzolized brown gleyed soil), six years ago experimental plots (each of 240 m²) were staked out (Fig. 1). Onto these, industrial lead-zinc-cadmium dust taken from the electrofilters of the lead and zinc works in Miasteczko Śląskie (Upper Silesian Industrial Region) was introduced, in doses of 0, 100, 500, 1000, and 2000 t km⁻² year⁻¹ (GRESZTA et al., 1987).

On the plots with dust, distinct changes were found in the higher vegetation, which with the highest doses consisted in complete disappearance of the undergrowth and dying of the trees—despite the six years elapsed from when the dust was introduced.

The aim of the present investigation was to assess the changes in the microflora and activity of microbiological decomposition of organic matter in both the control soil and the soil dosed with the dust.

For the study the top layer of the soil was sampled to a depth of about 4 cm, from the A_{0F+H} horizon, after loose litter had been swept aside.

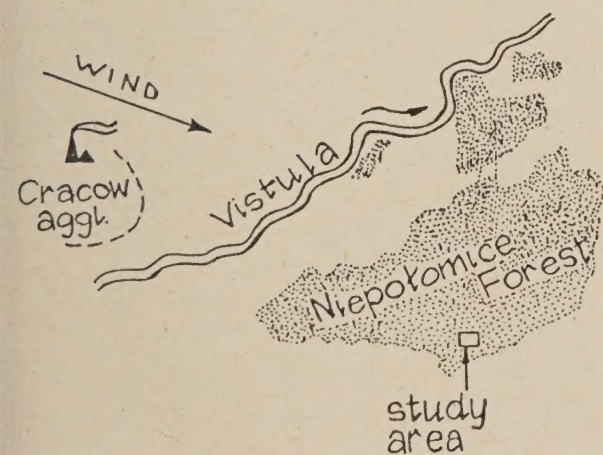


Fig. 1. Map of study area.

In the soil samples the content of nutrients, heavy metals, organic matter, and moisture content were determined. Of the microorganisms the number of algae, fungi, actinomycetes, and bacteria was assessed, taking into account the groups taking part in the cycling of compounds containing nitrogen, free of nitrogen, and compounds of phosphorus, as well as organisms decomposing proteins with release of H₂S.

Because decomposition of organic matter is connected with release of energy from the environment (PHILLIPSON, 1969; ODUM, 1982), in samples the total respiration of microorganisms was assessed by measuring the amount

of CO_2 evolved, and gas exchange (photosynthesis, respiration) in algae by measuring the amount of O_2 evolved or taken up. For comparative purposes these values were calculated into units of energy and given in Joules (J) per gramme of dry soil.

The results presented show the average values obtained during the growing season in 1987.

CHEMICAL CHARACTERISTICS OF THE SOILS

The soils were acid (pH 3.5 - 4.6) and contained trace amounts of nitrogen (0.001 and 0.021 $\text{mg} \cdot \text{g}^{-1}$ of dry soil, respectively, of the ammonia and nitrate forms).

The quantities of phosphorus, calcium, and magnesium were small, amounting to 0.20, 0.41, and 0.11 $\text{mg} \cdot \text{g}^{-1}$ of dry soil, respectively.

Potassium and sulphur occurred in greater amounts, respectively: 0.10, 28.1 for organic sulphur and 22.5 $\text{mg S-SO}_4 \cdot \text{g}^{-1}$ of dry soil.

Of the heavy metals in the soil there was most lead (0.1 - 34.2) followed by iron (3.9 - 8.1), zinc (0.1 - 4.4) and cadmium (0.03 - 4.7 $\text{mg} \cdot \text{g}^{-1}$ of dry soil). The content of metals increased with the dose of dust.

The content of organic carbon in the control soil was smaller (1840 mg C g^{-1}) than in soils with added dust (175.0 - 2120.0 mg C g^{-1} of dry soil).

The coefficient of soil moisture (the ratio of wet soil to dry soil weight) during the study period varied from 1.51 to 2.34.

Total number of
A - algae B - heterotrophic bacteria
C - fungi D - Actinomycetes

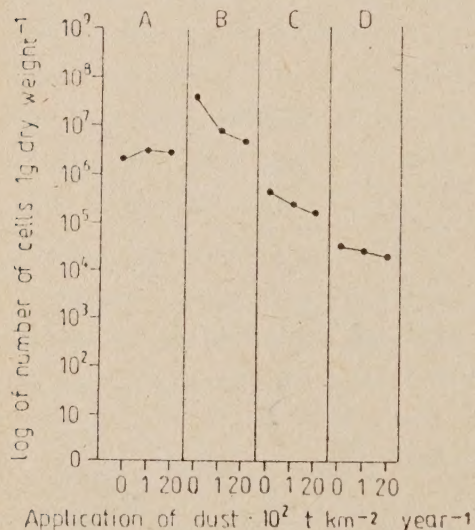


Fig. 2. Number of microorganisms in 1 g of dry soil: A - algae, B - heterotrophic bacteria, C - fungi, D - actinomycetes.

Bacteria:
A 1 • proteolytic 2 • ammonif. 3 • nitrif. l-st ph. 4 • denitrifying 5 + fixing N_2 anaerob.
B 1 • amylolytic 2 • cellulolytic
C 1 • phosphorus
D 1 • releasing H_2S

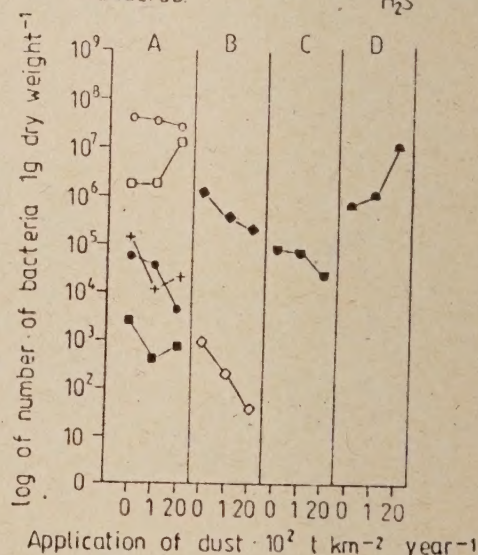


Fig. 3. Bacteria metabolizing various compounds: A - nitrogen ones, B - nitrogen-free ones, C - phosphate ones, D - sulphur ones.

MICROBIOLOGICAL CHARACTERISTICS OF THE SOILS

Of the algae, fungi, actinomycetes, and heterotrophic bacteria, the last were the most numerous group. The difference in favour of bacteria was large, amounting to 2 - 3 orders of magnitude (Fig. 2).

The smallest differences in number between the soils with added dust as compared with control ones were found in the case of fungi, and the greatest ones in the case of heterotrophic bacteria.

The number of algae was greater in soils to which dust had been added than in the control soil, and varied from 2.1 to 2.6×10^6 cells g^{-1} of dry soil (Fig. 2). In the control soil green algae distinctly predominated, mainly the genera *Chlamydomonas*, *Chlorohormidium*, *Stichococcus* and, to a much smaller degree, *Pseudococcomyxa*, with a complete absence of blue-green algae. Increases in the dose of dust in the soils were accompanied by an increase in the share of algae of the *Pseudococcomyxa* genus, which at the highest dose of dust ($2000 \text{ t km}^{-2} \text{ year}^{-1}$) were a virtual monoculture.

In the group of bacteria metabolizing nitrogen compounds, ammonifying bacteria were most numerous (10^7 cells g^{-1} of dry soil), and denitrifying ones ($10^6 - 10^7$ cells g^{-1} of dry soil) while the number of nitrifying bacteria was smallest, about $10^2 - 10^3$ cells g^{-1} of dry soil (Fig. 3A).

Among the bacteria metabolizing compounds free of nitrogen the number of amylolytic bacteria was on average 3 orders of magnitude greater than that of cellulolytic bacteria ($10^4 - 10^5$ and $10^2 - 10^3$ cells g^{-1} of dry soil, respectively) (Fig. 3B).

Phosphorus bacteria attained an abundance in the order of $10^5 - 10^6$ cells g^{-1} of dry soil (Fig. 3C), and the number of bacteria decomposing protein and releasing H_2S was similar to that of the denitrifying bacteria - about 10^6 cells g^{-1} of dry soil (Fig. 3D).

The number of microorganisms usually decreased as the dose of dust increased. Among the bacteria with varied biochemical properties the exception were denitrifiers and H_2S - releasing bacteria whose number was markedly greater in the soils with the largest doses of dust.

MICROBIOLOGICAL ACTIVITY OF THE SOILS

The average amount of energy released from the control soil in result of the metabolic activity of microorganisms was $9.8 \text{ J} \cdot g^{-1}$ of dry soil 24 h^{-1} (Fig. 4). With increasing doses of dust in the soil microbiological activity decreased, this being evidenced by the amount of energy released from the environment. With the highest dose of dust this value was $5.2 \text{ J} \cdot g^{-1}$ of soil 24 h^{-1} .

The coefficient of correlation expressing this relationship was high, amounting to $r = 0.91$ (Fig. 4).

Gas exchange in algae showed a decrease in photosynthetic activity and a little increase in respiration processes in soils to which dust had been added (Fig. 5). The ratio of photosynthesis (F) to respiration (R) decreased with increasing doses of dust, from 2.47 in the control soils to 0.96 in soils with the highest dose of dust, the correlation being $r = 0.86$ (Fig. 6). The decrease in F/R to under 1 indicated a preponderance of dissimilation processes in the soil with the highest dose of dust and a concurrent change in the role of algae, from the main producers of organic matter in the soil subsystem to its consumers.

S U M M A R Y

Besides bringing about changes in the higher flora, these industrial dusts introduced into the soils of the Niepołomice Forest distinctly lowered their microbiological activity on average by 40 % in comparison with the control soils.

They also inhibited the development of microorganisms, including most of the determined groups of bacteria, whose biological capacities were varied. However, they distinctly stimulated the development of denitrifying bacteria, of those fixing nitrogen anaerobically, and releasing H_2S during the decomposition of proteins, which might indicate poorer oxygenation in the soils, especially with the highest dose of dust.

In the soils with dusts greater development of algae was found, mainly of the *Pseudococcomyxa* genus, with concurrent recession of other genera of these microorganisms.

Despite the existence of any data in the world literature indicating the detrimental effects of industrial imissions on forest ecosystems as, for instance, shown by Grodziński et al. (1984), undertaking such investigation in one particular ecosystem is worthwhile because the kind of changes caused depend on habitat and are peculiar to it, and hence any conclusions drawn will not strictly apply to other subjects of investigation. Though nowhere in Poland is the pollution by industrial dust as great as in the experiment carried out in the

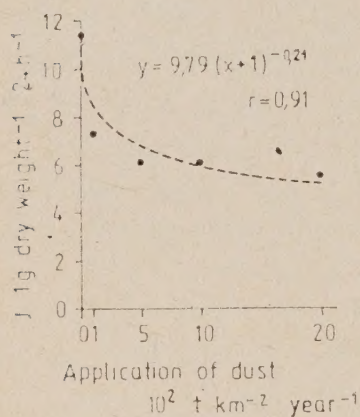


Fig. 4. Microbiological activity of soils

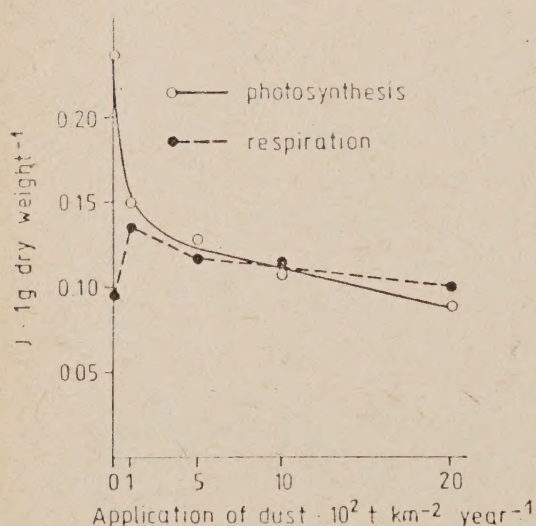


Fig. 5. Photosynthetic and respiratory activity of the algae.

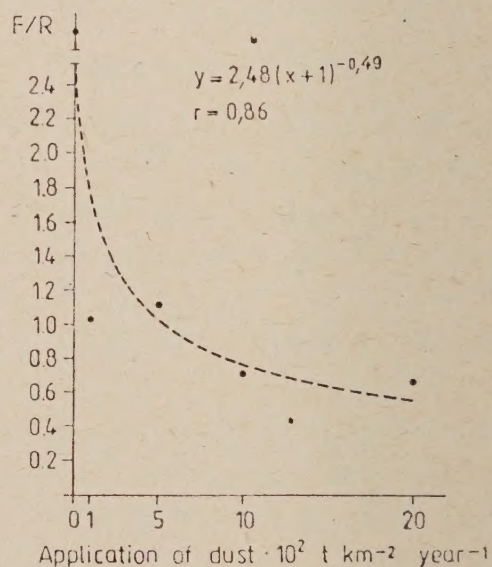


Fig. 6. Coefficient of gas exchange in algae, F/R (photosynthesis/respiration).

Niepołomice Forest, demonstration of the magnitude of the damage to which excessive pollution by industrial dust can lead, even when caused by its accumulation, indicates a pressing need for effective protective measures.

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Chlorella vulg. as bioindicator on soil herbicides

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As the application of some herbicides in agriculture was prevented by their long persistence in soil, there were postulated several mathematical models serving for estimations of herbicide desintegration in soil as it was influenced by various methodological and other factors. However, such a model describe the soil process of herbicide destruction as a function of hydrothermic factors. We underline therefore the high complexity of herbicide interactions in the soil where besides the prompt sorption and or chemical interactions also exists a lag phase induced by the slow adaptation of microflora to the new xenobiotics can be expected.

Recently a model of picloram (4-amino-3,5,5-trichloropikolinic acid) decomposition was postulated for processes of herbicide destruction after its contact with a soil (SCHABANOV et al., 1982). From the curves of pikloram decomposition it was concluded that after application into the soil the herbicide was first quickly inactivated with nonlinear kinetics caused by two simultaneous and independent processes which was followed by the inactivation exhibiting a constant rate.

From the above mentioned results we have deduced the importance of interactions between soil organic compounds and herbicides and of their mutual transformation. Previously we have demonstrated that due to the degradation of soil organic compounds by herbicides the amounts of water-soluble humic and fulvic acids were enhanced (GORDIENKO, 1983). These humic acid, as we demonstrated, created soluble complexes with herbicides (KALOUSKOVÁ, KUZNECOVA, GORDIENKO, KRUGLOV, 1983), which were toxic as Chlorella cells - test showed.

M A T E R I A L S A N D M E T H O D S

Microorganism used for testing: Chlorella vulgaris, strain 157 from the collection of Leningrad University was cultivated on a liquid broth described by Gromov containing in 1000 ml: KH_2PO_4 -0.2 g, NaH_2PO_4 -0.2 g, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ -0.2 g, KNO_3 -1 g, CaCl_2 -0.15 g, glucose-5 g, peptone-1 g, solution of microelements-1 ml; pH 7.0. For testing of phytotoxicity the cells were cultivated under permanent illumination to $\text{OD}_{536} = 0.090$ -0.100 which was equivalent to 3.0-5.5 μg dry weight per ml. For testing of phytotoxicity 2 ml of such algal culture were diluted by 10 ml of sterile medium described by Elman containing in 1000 ml KNO_3 -0.4 g, KH_2PO_4 -0.4 g, $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$ -0.2 g and 4 ml of effector solution were added. Such cultures were incubated in permanent illumination for 72 hours and afterwards the changes of biomass were measured spectrophotometrically at 536 nm. Content of chlorophyll was measured at 636 nm in ultrasound homogenates of algae in 90 % ethanol (4 min., 21.7 KHz-instr. Tesla UAA 112). Results were plotted in % of control culture values versus the concentration of effector (b) expressed in weight to volume values.

Effectors. Simazine (reagent grade) (S) - 2-chloro-4,6-diethylamino-1,3,5-triazin; diuron (D) - 3(3,4-dichlorophenyl)-1,1-dimethylurea both obtained from VASCHNIL, Leningrad. The preparation of humic acid was isolated from peats found near Jirpen river and was of medium (50 000) molecular weight.

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The solutions of simazine plus humic acid (HA-S) were prepared with molar ratios 1:1, 1:2, 1:10, 1:20 where the herbicide concentration was 0.048, 0.096, 0.240, 0.480 and 0.960 mg per 1 000 ml at pH 7.0 and 5.5.

The solutions of diuron plus humic acid (HA-D) were prepared with molar ratios 1:0.01, 1:0.5, 1:1, 1:2 and 1:20 where the herbicide concentrations were 0.5, 5, 27, 96 and 960 μ g per 100 ml at pH 7.0 and 5.5.

Assay of herbicide phytotoxicity: Algological method described by BALICKA et WĘGRZYN (1981) was employed.

Electron microscopy. The cells were harvested by gentle centrifugation (300 g) and fixed in 4 % glutaraldehyde buffered by 0.05 M cacodylate buffer pH 7.2 overnight and postfixed in cold 2 % KMnO_4 for 6 hours. Cells washed by cacodylate buffer were embedded in agar and dehydrated in alcohol series and absolute acetone and embedded in Vestopal W. Ultrathin sections were viewed under JEM 100-B microscope (60 kV).

R E S U L T S

The first herbicide tested was simazine (S) which stimulated for 23 % the out growth of Chlorella culture between 0.04 and 0.2 mg/ml at pH 7.0. At pH 5.5 the growth was not influenced by the above given concentrations of herbicide (Fig. 1). Higher concentrations of S inhibited the outgrowth of cultures at both pH values. The minimal values of OD_{535} were found in cultures growing with 0.96 mg herbicide per ml and reached 62.5 % of control.

The values of chlorophyll content in cultures of Chlorella grown in the presence of S are plotted in Fig. 2. At pH 7.0 an enhancement of chlorophyll amount was observed up to 0.3 mg/l herbicide at pH 7.0. At higher concentrations or at pH 5.5 the amount of chlorophyll was lower than in the control culture.

When S was added simultaneously with humic acids (HA) (0.05 mg/l or 0.096 mg/l herbicide per 0.05 mg/l HA) the stimulation of outgrowth and its subsequent inhibition was noted as well as with pure S at pH 7.0 (Fig. 1) but the effect was shifted up to higher values in the whole range of herbicide concentrations. At pH 5.5 the growth was stimulated already by the lowest concentration of S and the value of outgrowth were shifted up again.

When S-HA were added the amount of chlorophyll was higher than the control at pH 7.0 in the whole range of herbicide concentrations tested. At pH 5.5 the inhibition was apparent from 0.2 mg S per l (Fig. 2).

The second herbicide tested was diuron (D) which in concentrations between 0.5 and 5 μ g/l and at both pH values was for about one order of magnitude more inhibitory than S for the outgrowth of Chlorella cultures (Fig. 2). The same was valid for chlorophyll contents of cultures (Fig. 4).

When humic acids were added simultaneously with (D), the inhibitory effect of herbicide on culture growth was partly compensated over the whole range of concentrations at both pH values. The combination of growing concentrations of herbicide with constant amount of humic acid (0.048 μ g/ml) was stimulatory up to 0.17 μ g/ml D at pH 7.0 and the same was valid up to 0.02 μ g/l D at pH 5.5.

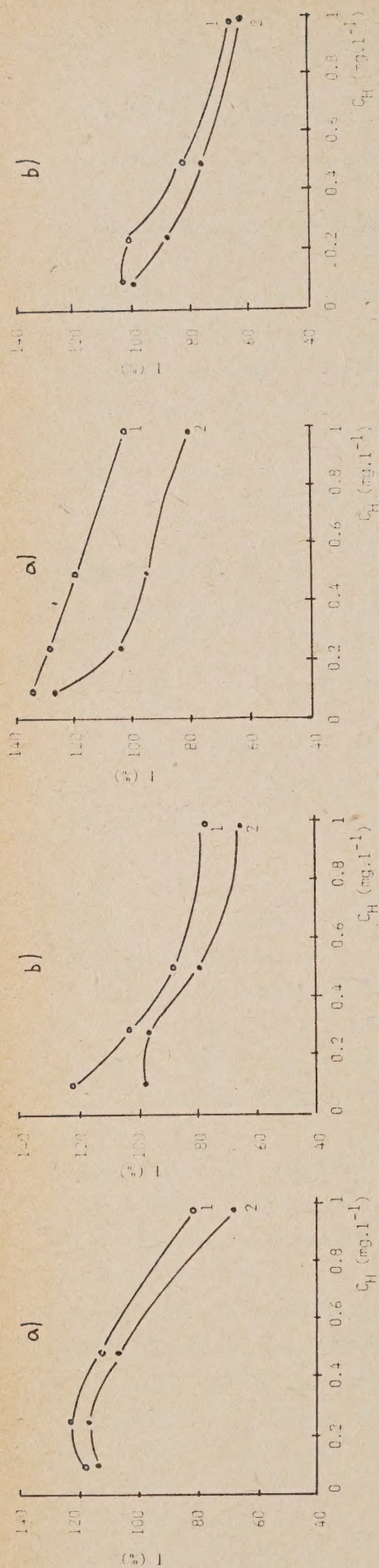


Fig. 1. Influence of Simazine on growth of Chlorella cells. a) pH=7.0, b) pH=5.5. 1 - Humic acid+Simazine, 2 - Simazine.

Fig. 2. Influence of Simazine on chlorophyll contents of Chlorella cells. a) pH=7.0, b) pH=5.5. 1 - Humic acid+Simazine, 2 - Simazine.

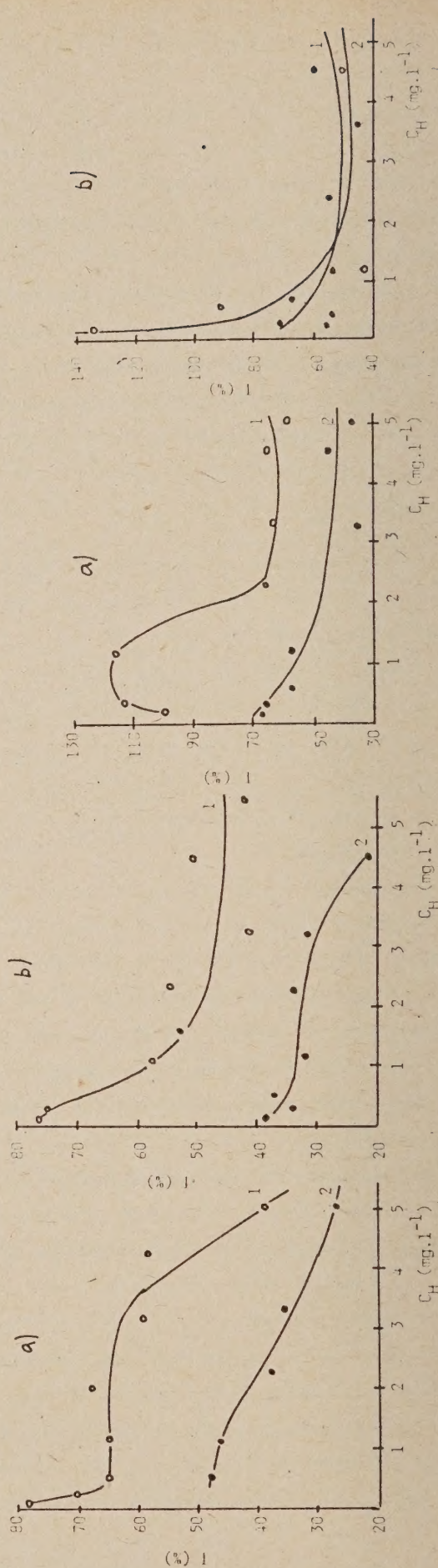


Fig. 3. Influence of Diuron on growth Chlorella cells. a) pH=5.5, b) pH=7.0. 1 - Humic acid+Diuron, 2 - Diuron.

Fig. 4. Influence of Diuron on chlorophyll in Chlorella cells.

a) pH=5.5, b) pH=7.0. 1 - Humic acid+Diuron, 2 - Diuron.



A



B



C



D

Fig. 5. Chlorocella cells. A - Simazine, few starch, stacking of thylakoids (84 000 x), B - Simazine + Humic acid, no starch, stacking of thylakoids (45 000 x), C - Diuron + Humic acid, no starch, stacking of thylakoids (45 000 x), D - Control (33 000 x). P - pyrenoid, S - starch, N - nucleus, A - autolysed cell. Arrows indicate thylakoids. The bar marker indicates 500 nm.

The ultrastructural criteria may be therefore suggested as an important indicator of herbicide action. The observed changes were the stacking of thylakoids and disappearing of starch grains (Fig. 5). The stacking of photosynthetic membranes was most probably consistent with the previously reported binding of herbicides to the chloroplast membranes (OETTMEIER et al., 1981) and localization of diuron target to the photosystem II (GRUMBACH, 1981) particularly to its photosynthetic electron transport (VERMAAS et al., 1983). The inhibition of photosynthesis resulted of course in the disappearing of reserve starch. The persistence of the observed ultrastructural changes after complexing of herbicides with humic acids showed obviously new aspects of herbicide action.

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Influence of fertilizers on microarthropods in erosion-free and erosion-affected soils of tobacco plantations

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Constant anthropogenic effect of agrocenoses on the soil considerably affects its biological components directly participating in the development and maintenance of its fertility. Soil invertebrates, along with the microflora, form an inevitable link in the chain of biological circulation of substances.

Agrocenosis microarthropods are represented by specific groups that develop as a result of strict selection. Peculiarities of structure and dynamics of that complex have not been sufficiently studied yet. Annual soil ploughing, complete absence of multilayer litter, poor supply of organic substances necessary for nutrition, as well as influence of various agrotechnical factors result in the reduction of microarthropod groups in arable soils.

A considerable number of reports deal with the studies of fertilizer effects on the microarthropod complex in arable soils (BLINNIKOV, 1983; ZAISEV, 1984; KAPIN, 1983; and others). Such works have not been conducted in Abkhazia before. The aim of the present research is to study influence of different fertilizers on the microarthropod complex of tobacco plantations having soils characterized by different degree of washout.

MATERIALS AND METHODS

The material was collected on the experimental plots of the Abkhazian Tobacco Station in May and September, 1986. The samples were taken in the course of the experiment "Agrochemical bases of soil fertility reclamation".

Four types of soil, according to the degree of erosion, have been investigated: free from erosion, with mild erosion, with moderate erosion and with strong erosion. Three experimental variants were used: Variant I - with complete mineral fertilizer; Variant II - with green manure; Variant III - with stubbles of vetch and oats and complete mineral fertilizer. Unfertilized plots served as controls.

In each variant of each type of soil, sampling was performed with ten-fold replication from the depth up to 15 cm (from 3.9 cm²). Samples were selected at random. In both periods, a total of 320 soil samples were collected. The samples were treated using the routine methods.

The author thanks Dr. I. D. Khvartskhia, Director of the Abkhazian Tobacco Station, for giving her the opportunity to conduct field research.

RESULTS AND DISCUSSION

In May, the average number of microarthropods was 2 161 individuals per sq. meter (Oribatei - 45 %, Collembola - 42 %, and Gamasidae - 11 %).

In the soils free from erosion, maximum numbers of all groups of microarthropods were obtained from control samples (Tab. 1). Application of fertilizers resulted in the reduction

Tab. 1. Numbers of microarthropods in the soil of tobacco plantations (thousand individuals/ /sq. meter).

Record period	Groups		Erosion-free soil			
			K	I	II	III
May	Collembola	1	2.5 $\pm$ 1.1	-	-	0.5 $\pm$ 0.3
	Gamasida	2	0.4 $\pm$ 0.2	-	0.1 $\pm$ 0.1	-
	Oribatei (1,n)	3	0.4 $\pm$ 0.3	-	0.1 $\pm$ 0.1	0.1 $\pm$ 0.1
	Oribatei (imago)	4	2.2 $\pm$ 0.8	-	-	0.1 $\pm$ 0.1
	Oribatei	5	2.6 $\pm$ 1.1	-	0.1 $\pm$ 0.1	0.2 $\pm$ 0.2
	Σ microarthropods	6	5.8 $\pm$ 2.4	-	0.2 $\pm$ 0.2	0.8 $\pm$ 0.4
September	Collembola	7	-	0.5 $\pm$ 0.3	3.5 $\pm$ 1.4	1.8 $\pm$ 0.7
	Gamasida	8	0.3 $\pm$ 0.2	0.5 $\pm$ 0.2	2.7 $\pm$ 0.9	2.8 $\pm$ 0.8
	Oribatei (1,n)	9	0.1 $\pm$ 0.1	0.3 $\pm$ 0.2	2.3 $\pm$ 1.1	0.3 $\pm$ 0.2
	Oribatei (imago)	10	0.6 $\pm$ 0.2	4.0 $\pm$ 1.4	10.5 $\pm$ 2.4	4.1 $\pm$ 1.6
	Oribatei	11	0.7 $\pm$ 0.3	4.3 $\pm$ 1.7	12.9 $\pm$ 2.7	4.4 $\pm$ 1.6
	Σ microarthropods	12	1.0 $\pm$ 0.4	5.6 $\pm$ 2.9	19.0 $\pm$ 4.4	8.3 $\pm$ 2.4

	Soil with mild erosion				With moderate erosion			
	K	I	II	III	K	I	II	III
1	1.3 $\pm$ 0.9	0.2 $\pm$ 0.1	0.6 $\pm$ 0.6	0.1 $\pm$ 0.1	0.5 $\pm$ 0.4	0.2 $\pm$ 0.2	0.2 $\pm$ 0.2	0.9 $\pm$ 0.6
2	0.3 $\pm$ 0.3	0.2 $\pm$ 0.2	0.2 $\pm$ 0.2	-	0.2 $\pm$ 0.1	0.2 $\pm$ 0.1	-	-
3	0.2 $\pm$ 0.2	0.1 $\pm$ 0.1	0.8 $\pm$ 0.8	-	0.2 $\pm$ 0.1	0.6 $\pm$ 0.3	-	-
4	1.4 $\pm$ 0.6	1.1 $\pm$ 0.8	0.3 $\pm$ 0.2	0.6 $\pm$ 0.3	1.0 $\pm$ 0.6	1.5 $\pm$ 0.5	0.6 $\pm$ 0.3	-
5	1.6 $\pm$ 0.7	1.2 $\pm$ 0.8	1.1 $\pm$ 1.0	0.6 $\pm$ 0.3	1.2 $\pm$ 0.6	2.1 $\pm$ 0.7	0.6 $\pm$ 0.3	-
6	3.2 $\pm$ 0.8	1.7 $\pm$ 0.9	2.0 $\pm$ 1.9	0.7 $\pm$ 0.4	2.0 $\pm$ 1.0	2.5 $\pm$ 0.8	0.8 $\pm$ 0.4	0.9 $\pm$ 0.6
7	-	0.1 $\pm$ 0.1	0.9 $\pm$ 0.5	0.5 $\pm$ 0.3	-	0.1 $\pm$ 0.1	0.1 $\pm$ 0.1	0.4 $\pm$ 0.4
8	0.9 $\pm$ 0.4	0.3 $\pm$ 0.2	1.8 $\pm$ 0.6	0.6 $\pm$ 0.3	-	-	0.3 $\pm$ 0.2	0.2 $\pm$ 0.1
9	1.0 $\pm$ 0.4	0.2 $\pm$ 0.2	0.4 $\pm$ 0.6	0.2 $\pm$ 0.1	0.1 $\pm$ 0.1	-	0.2 $\pm$ 0.1	0.1 $\pm$ 0.1
10	1.0 $\pm$ 0.4	2.5 $\pm$ 0.7	6.8 $\pm$ 1.8	0.9 $\pm$ 0.3	1.6 $\pm$ 0.7	0.4 $\pm$ 0.3	1.0 $\pm$ 0.5	0.8 $\pm$ 0.4
11	2.1 $\pm$ 0.7	2.7 $\pm$ 0.3	8.2 $\pm$ 2.0	1.1 $\pm$ 0.3	1.7 $\pm$ 1.0	0.4 $\pm$ 0.3	1.2 $\pm$ 0.5	0.9 $\pm$ 0.4
12	3.0 $\pm$ 1.0	3.1 $\pm$ 0.7	10.9 $\pm$ 2.8	2.3 $\pm$ 0.4	1.7 $\pm$ 1.0	0.5 $\pm$ 0.3	1.7 $\pm$ 1.2	1.6 $\pm$ 0.7

	Soil with strong erosion			
	K	I	II	III
1	0.5 $\pm$ 0.3	3.8 $\pm$ 2.4	1.8 $\pm$ 1.6	2.0 $\pm$ 1.4
2	0.2 $\pm$ 0.1	1.4 $\pm$ 0.7	-	0.1 $\pm$ 0.1
3	0.2 $\pm$ 0.1	1.0 $\pm$ 0.4	-	0.2 $\pm$ 0.2
4	0.6 $\pm$ 0.6	1.8 $\pm$ 0.6	0.1 $\pm$ 0.1	0.6 $\pm$ 0.6
5	0.7 $\pm$ 0.4	2.5 $\pm$ 0.7	0.1 $\pm$ 0.1	0.8 $\pm$ 0.3
6	1.5 $\pm$ 0.7	7.9 $\pm$ 2.7	1.9 $\pm$ 1.6	3.0 $\pm$ 1.6
7	-	0.1 $\pm$ 0.1	0.2 $\pm$ 0.1	0.2 $\pm$ 0.2
8	-	0.1 $\pm$ 0.1	0.5 $\pm$ 0.2	0.1 $\pm$ 0.1
9	-	0.1 $\pm$ 0.1	0.2 $\pm$ 0.1	0.3 $\pm$ 0.3
10	1.6 $\pm$ 0.4	0.2 $\pm$ 0.5	2.5 $\pm$ 0.5	0.7 $\pm$ 0.4
11	1.6 $\pm$ 0.4	2.6 $\pm$ 0.5	2.7 $\pm$ 0.6	1.0 $\pm$ 0.7
12	1.6 $\pm$ 0.4	2.8 $\pm$ 0.5	3.4 $\pm$ 0.5	1.3 $\pm$ 0.9

of microarthropod numbers in Variant III and in their complete disappearance in Variants I and II.

In the soils with mild erosion, the greatest numbers of microarthropods were also noted in control samples, and application of fertilizers decreased their population density.

In the soils with moderate erosion, microarthropod population density is almost the same in control and Variant I samples, while in Variants II and III it decreases.

In the soils with strong erosion, application of mineral fertilizers caused an insignificant increase in the numbers of microarthropods.

Thus, application of fertilizers in different combinations reduced, in most cases, the numbers of microarthropods.

Statistical significance of differences, according to Student, is low.

In September, the total number of microarthropods was significantly higher (4 245 individuals per sq. meter). Ratio of the main groups had sharply changed: Oribatei dominated (72 %), Collembola and Gamasidae making up 14 % and 16 %, respectively.

Marked reaction of microarthropods to the application of fertilizers was noted. In the soils free from erosion, application of fertilizers caused a sharp increase in the numbers of all microarthropod groups, especially when green manure was used. The degree of significance of these differences, according to Student, is high.

In the soils with mild erosion, a statistically significant increase in the numbers of microarthropods occurred after the application of green manure, while in the other variants differences are doubtful.

In the soils with moderate erosion, there were no significant changes in the microarthropod complex after the application of fertilizers.

In the soils with strong erosion, green manure and complete mineral fertilizer caused a sharp increase in the numbers of microarthropods. Statistical significance of differences is high.

The mean microarthropod number, according to the two records, made up 3 206 individuals per sq. meter. Oribatei dominated (58 %), Collembola and Gamasidae making up 29 % and 13 %, respectively. The numbers of microarthropods in the investigated agrocenosis are considerably lower than that in the soil of natural zonal biocenosis where they make up more than 60 000 individuals per sq. meter (TARBA, in press).

In soil under tobacco, considerable seasonal variations in the numbers of all groups of microarthropods, as well as considerable changes in the ratio of different groups have been noted (Fig. 1).

Application of fertilizers causes changes in microarthropod population. Their extent seems to depend greatly on the meteorological conditions of the vegetative season. Influence of other factors may be much greater than influence of fertilizers and soil type (CHENOVA, 1981, TITSEV, 1984). Thus, in autumn, fertilizers, especially green manure, resulted, in most cases, in an increase in the numbers of the main microarthropod groups, while there was

no change in the composition in the soils with different degree of erosion, and no significant differences.

Significant differences between control samples of soils with and without application of mineral fertilizers. Only green

manure and stubbles, together with mineral fertilizers, caused a sharp increase in the numbers of microarthropods in the free from erosion soils and soils with mild erosion. Statistical significance of these differences is high (according to Student).

Forty-two species of Oribatei (36 genera, 23 families) have been found in the soil of tobacco plantations (Tab. 2). It is significantly less than in natural zonal biocenoses. Thus, in the mixed forest of Kolkhida type, 102 species of Oribatei were discovered (TARBA, in press).

Oribatei population is characterized by low quantities and limited suit of abundant species. Large record series made it possible to reveal the course of the cumulative curve of the species detected (Fig. 2). Fauna diversity is exhausted only after a great number of samples (320). The slope of the curve reflecting an increase in the numbers of species in a single sample becomes less steep after 140 samples. A total of 26 species were registered during the first record period. September sampling exhibits a new rise of the curve which becomes gently sloping only after additional 90 samples. During that period, another 16 species were detected. The suit of active species have not evidently been exhausted, as most of them are extremely scanty; therefore, repeated tests will probably supplement the list of Oribatei species. Similar pattern was noted by N. M. CHERNOVA (1984) for Collembola groups.

According to the results of average number estimations, five dominant species may be singled out (dominance and subdominance thresholds make up 5 % and 2 %, respectively): Eremotelba geographica, Punctoribates punctum, Oteroppiella plumata, Pergalumna minor, Tectocephus velatus. The degree of their dominance is high (62 %).

The group of subdominant species is represented by 7 species: Scheloribates laevigatus, Oppeiella nova, Pilogalumna tenuiclava, Minunthozetes pseudofusiger, Graptoppia foveolata, Galumna obvia, Phauloppia longiporosa. Their total abundance makes up 21 %.

The group of scanty species consists of 30 species, 16 of which are represented by a single sample. Their quantitative participation in the group makes up 17 %.

Incidence of all Oribatei species is very low, making up 15 % in the most abundant ones, Eremotelba geographica and Punctoribates punctum (320 samples).

Numerical ratio of common and rare species is an important characteristics of the specific structure. In stable societies, this ratio is expressed by a curve similar to that of Rounciar (Fig. 3).

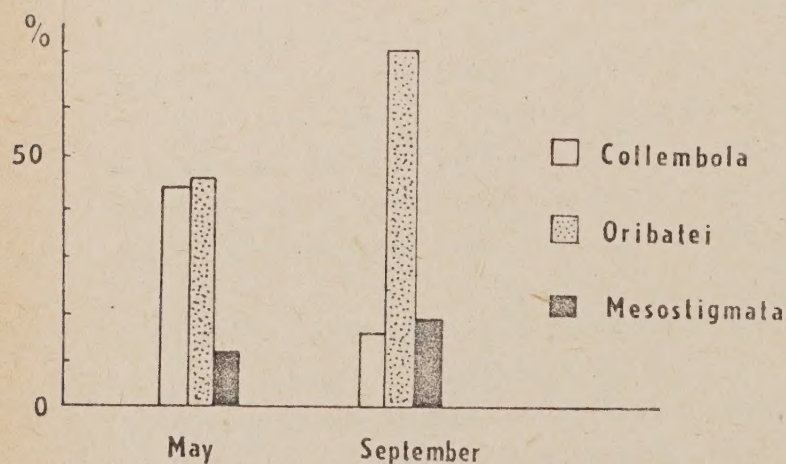


Fig. 1. Changes in the ratio of the main microarthropod groups.

Ratio of abundant species changes seasonally. In spring, Punctoribates punctum, Scheloribates punctum, Scheloribates laevigatus, Eremobelba geographica, Minunthozetes pseudofusiger, Pilagalumna tenuiclava, Ctenoppiella plumata dominated. In autumn, Eremobelba geographica, Punctoribates punctum, Ctenoppiella plumata, Pergalumna minor, Tectocephus velatus were most numerous. As we see, only two species belong to both dominant groups.

Analysis of species composition has shown that almost all species mentioned as characteristic of the Kolkhida type mixed forest are present in the examined soils. Eremulus flagellifer, Graptoppia foveolata and Romanobates reticulatus have been discovered in Abkhazia for the first time.

Zoogeographical analysis of the species composition has shown that in Oribatid fauna of tobacco plantations widespread species prevail: 9 Holarctic, 6 Transpalearctic, 11 Euro-Siberian, 2 European and 6 Mediterranean.

Analysis of Oribatei population has shown that about 43 % of species belong to the morpho-ecological type of surface dwellers, 31 % are small inhabitants of soil pores, and 26 % are unspecialized eurybiontic species. Deep soil inhabitants have not been discovered.

The investigations failed to reveal any effect of fertilizers on species composition of Oribatids, as well as any differences in the complex of Oribatei in the soil characterized by different degree of erosion.

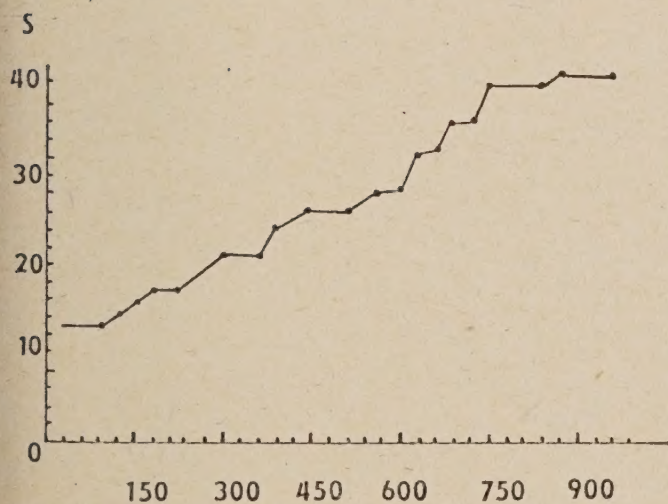


Fig. 2. Cumulative curve of the increase in the numbers of Oribatei species with the increase of sample volume. Axis of abscissae - number of records (each record - 30 samples), axis of ordinates - number of species.

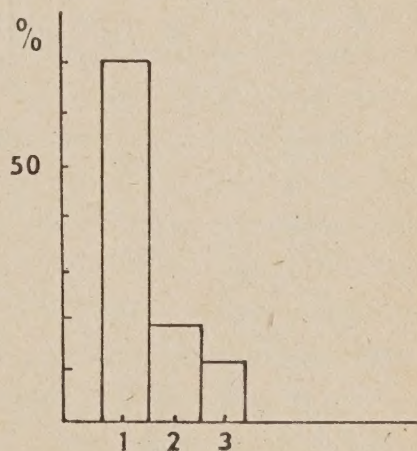


Fig. 3. Ratio of species numbers (in % to their total number), with different abundance in the Oribatei group. Species percentage in the total sample: 1: < 2 %, 2: 2-5 %, 3: > 5 %.

Tab. 2. Numbers of species in Oribatei population of tobacco plantations.

Species	Numbers of individuals	D
<i>Eremobelba geographica</i> Berl., 1908	112	23.0
<i>Punctoribates punctum</i> (Koch, 1839)	81	16.5
<i>Ctenoppiella plumata</i> Gordeeva, 1988	42	8.6
<i>Pergalumna minor</i> (Willm., 1938)	39	8.0
<i>Tectocephus velatus</i> Michael, 1880	31	6.1
<i>Graptoppia foveolata</i> (Paoli, 1908)	20	4.0
<i>Scheloribates laevigatus</i> (Koch, 1836)	19	3.8
<i>Oppiella nova</i> (Oudem., 1902)	18	3.6
<i>Pilogalumna tenuiclava</i> (Berl., 1908)	17	3.4
<i>Minunthozetes pseudofusiger</i> (Schweizer, 1922)	16	3.2
<i>Galumna obvia</i> (Berl., 1915)	11	2.2
<i>Phauloppia longiporosa</i> Kuliew, 1968	10	2.0
<i>Protoribates capucinus</i> Berl., 1908	8	1.6
<i>Ceratozetes bulanovae</i> Kuliew, 1962	8	1.6
<i>Ceratozetes</i> sp.	8	1.6
<i>Ramusella mihelčiči</i> (Perez-Inigo, 1965)	7	1.4
<i>Phthiracarus</i> sp.	5	1.0
<i>Microzetes auxiliaris</i> Grandj., 1936	5	1.0
<i>Tectoribates</i> sp.	4	
<i>Suctobelbella</i> sp.	3	
<i>Oppia</i> sp. 1	3	
<i>Achipteria italicus</i> (Oudem., 1913)	3	
<i>Ctenoppiella obsoleta</i> (Paoli, 1908)	3	
<i>Insculptoppia insculpta</i> (Paoli, 1908)	2	
<i>Chamobates</i> sp.	2	
<i>Pergalumna nervosa</i> (Berl., 1915)	2	
<i>Cosmochthonius lanatus</i> (Michael, 1887)	1	
<i>Nanhemannia nana</i> (Nic., 1885)	1	
<i>Rysotritia ardua</i> v. <i>penicillata</i>	1	
<i>Liodes tgeleproctus</i> (Hermann, 1804)	1	
<i>Camisia horrida</i> (Hermann, 1804)	1	
<i>Metabelba rara</i> B. -Z., 1965	1	
<i>Ceratoppia quadridentata</i> (Haller, 1880)	1	
<i>Eremulus flagellifer</i> Berl., 1908	1	
<i>Oppiella</i> sp.	1	
<i>Xenillus tegeocranus</i> (Hermann, 1804)	1	
<i>Oribatula tibialis</i> (Nic., 1855)	1	
<i>Oribatula pallida</i> Banks, 1906	1	
<i>Eporibatula rauschenensis</i> Sellnick, 1928	1	
<i>Zygoribatula exilis</i> (Nic., 1855)	1	
<i>Romanobates reticulatus</i> Feider, Vasiliu, 1970	1	

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Einfluss der Stickstoffdüngung auf die kleinen wirbellosen Bodentiere - Acarina und Collembola

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E I N F Ü H R U N G

Mit der steigenden Intensivierung der Landwirtschaft sind die in den Boden eingeführten Mengen der Mineraldünger - besonders der Stickstoffreichen - immer grösser. Ohne Zweifel kann das nicht gleichgültig sein für die vorhandenen Zusammenhänge zwischen der Anzahl, Qualität und Entwicklung der Bodenorganismen einerseits und der physisch-chemischen Beschaffenheit der Boden andererseits. Je grösser werden die Mengen der eingeführten Mineraldünger desto mehr werden die Zusammenhänge gestört.

Die in den Jahren 1985 - 1987 durch uns geführten Untersuchungen hatten das Ziel den Einfluss der Stickstoffdüngung auf die kleinen wirbellosen Bodentiere in den Agrozenosen zu schätzen. Die Aufmerksamkeit auf diese zwei Gruppen der wirbellosen Bodentiere - Acarina und Collembola, wurde deshalb gelenkt, weil sie beim zahlreichen Auftreten einen empfindlichen Anzeiger für die Änderungen, welche unter dem Einfluss antropogener Faktoren in dem Boden vorkommen, darstellen.

U N T E R S U C H U N G S M E T O D E

Die Untersuchungen wurden auf einem Produktionsfeld mit angebautem Mais angelegt. Der Boden - ein sandiger Lehm - mit dem pH-Wert = 6,3 hatte den Gehalt von 1,2 % organischer Substanzen. Die Stickstoffdüngung mit Ammonsalpeter wurde vor der Saat des Mais durchgeführt. Es waren folgende Düngergaben: N-90 kg/ha; N-180 kg/ha; N-270 kg/ha und Kontrolle mit N-0 kg/ha. Die Grösse der Fläche in jeder Kombination war 1 ha. Unmittelbar nach der Maisaussaat wurde das Feld mit Simazin 80 WP in einer Gabe von 1,9 kg/ha bespritzt.

Zur Abschätzung des Einflusses der Stickstoffdüngung auf die Acarina und Collembola wurden in dem Leitraum von Mai bis September und in Abständen von zwei Wochen, aus dem Boden und aus der Tiefe von 0 - 15 cm Stichproben bezogen. Es wurden jedesmal von jedem einzelnen Objekt 10 Stichproben bezogen. Die kleinen wirbellosen Bodentiere wurden im Tullgren - Gerät verscheucht.

In der selben Zeit wurden Bodenproben zur Feststellung des Mineralstickstoffgehalts bezogen.

E R G E B N I S S E

Der Gehalt des Mineralsstickstoffes in der Scholle war von der Menge des Düngers abhängig (Abb. 1). Die höchsten Werte sind in der Monatswende Mai und Juni hervorgetreten. Besonders hohe mineral N-Werte wurden im Boden auf dem Felde mit der N-gabe 270 kg/ha beobachtet. Der Boden aus dem ungedüngtem Felde enthielt kaum Spuren von Mineral-N. Im Verlaufe der Vegetationszeit, in den Monaten Juni bis August, fiel der Gehalt des Mineral-N in allen untersuchten Kombinationen deutlich herab (Abb. 1).

Die Anzahl, in den einzelnen Jahren, der kleinen wirbellosen Bodentiere, umgerechnet auf 1 m^2 , wurde auf der Abb. 2 vorgeführt. Ausser den Saisonänderungen wurde auch der Einfluss der hohen Stickstoffgaben auf die Anzahl der untersuchten Bodentiere sichtbar.

Von den Collembolen wurden 12 Arten untersucht, dabei zu den zahlreichsten gehörten: Onychiurus armatus (Tullberg), Tullbergia krausbaueri (Börner), Folsomia fimetaria (Linneus) und Hypogastrura assimilis (Krausbauer). Weniger zahlreich waren die Arten: Isotoma notabilis (Schaft.), Isotoma viridis (Bourl.) und Isotoma olivacea (Tullb.). Das Vorkommen der anderen Arten war sporadisch.

Im Falle der Acarina, wurden, wegen grösser taxonomischer Schwierigkeiten, nur die Acaridida, Oribatidae - und von den Raubtieren - Pergamasus sp. und Rhodacarellus sp. abgesondert.

Auf dem mit Ammonsalpeter gedüngtem Felde, in einer N-Gabe von 90 kg/ha, wurde weder eine unmittelbare noch mittelbare negative Wirkung der mineralen Stickstoffformulierungen gegen die untersuchten wirbellosen Bodentiere beobachtet. Die Anzahl der Bodentiere, besonders der Acarina, war grösser als in den anderen Düngungskombinationen; im Jahre 1987 war die Anzahl sogar grösser als in der Kontrolle (Abb. 1). Es mösse das suggerieren, dass eine Gabe von 90 kg/ha für die Entwicklung der Acarina eine stimulierende Wirkung hat. Das betrifft auch die Collembolen. Anstieg der Anzahl von Acarina und Collembolen wurde besonders in den Monaten Mai und Juni beobachtet, obwohl in diesem Zeitraum grössere Werte von Ammonstickstoff und salpetersauren Verbindungen ermittelt wurden.

Zweifache Vergrösserung der Ammonsalpetergaben, wie das in der Abb. 2 sichtbar ist, hat weder eine reduzierende noch stimulierende Wirkung für die wirbellosen Bodentiere nachgewiesen.

In der Kombination mit 270 kg N/ha wurde in allen Untersuchungsstufen immer aus dem Boden die kleinste Zahl von Acarina und Collembolen ausgesondert (Abb. 2). Im Verhältniss zur Kontrolle waren die Unterschiede im Mai und Juni am grössten - im Durchschnitt um 8 bis 10 Tausend Einzelwesen pro m^2 . Das ist ein Beweis, dass so grosse Stickstoffgaben für die kleinen wirbellosen Bodentiere schädlich sind, wahrscheinlich wegen zarter Hautbedeckung der Acarina. Besonders betrifft das die saprophagen Milben: Acaridida und Oribatidae.

Änderungen in der Zahl der wirbellosen Bodentiere beweisen, dass sie von der Menge des ausgebrachten Düngers abhängig sind. Stickstoffgabe von 90 kg/ha wirkt stimulierend auf die Collembolen und die Acarina. Die Gaben von 180 kg/ha wirkten weder reduzierend noch stimulierend auf die untersuchten wirbellosen Bodentiere. N-Gaben von 270 kg/ha wegen seiner reduzierenden Wirkung waren für die Springschwänze und Milben schädlich.

Beachtenswert ist die Beobachtung dass einige Arten von Collembolen nach den N-Gaben 90 und 180 kg/ha immer in grösserer Anzahl gesammelt wurden als in der Kontrolle. Betrifft das solche Arten wie: Tullbergia krausbaueri (Börner), Onychiurus armatus (Tullb.) oder Hypogastrura assimilis (Krausb.). Diese Arten, weil sie am öftesten gesammelt wurden - 46 % der Gesamtzahl gesammelter Springschwänze - kann man zu den wenig Stickstoffempfindlichen zählen.

Ähnliche Untersuchungen wurden früher durch HRYNIOK (1962), KOT (1972) und MYKOW (1972) geführt. Sie haben gezeigt dass der Einfluss auf lebende Bodenorganismen von Grösse der Düngergaben abhängig ist. Sie haben auch bemerkt, dass möglicherweise bei höheren Stickstoffgaben, sich im Boden giftige Nitritverbindungen entwickeln können, deren Anwesenheit im Boden schädlich ist.

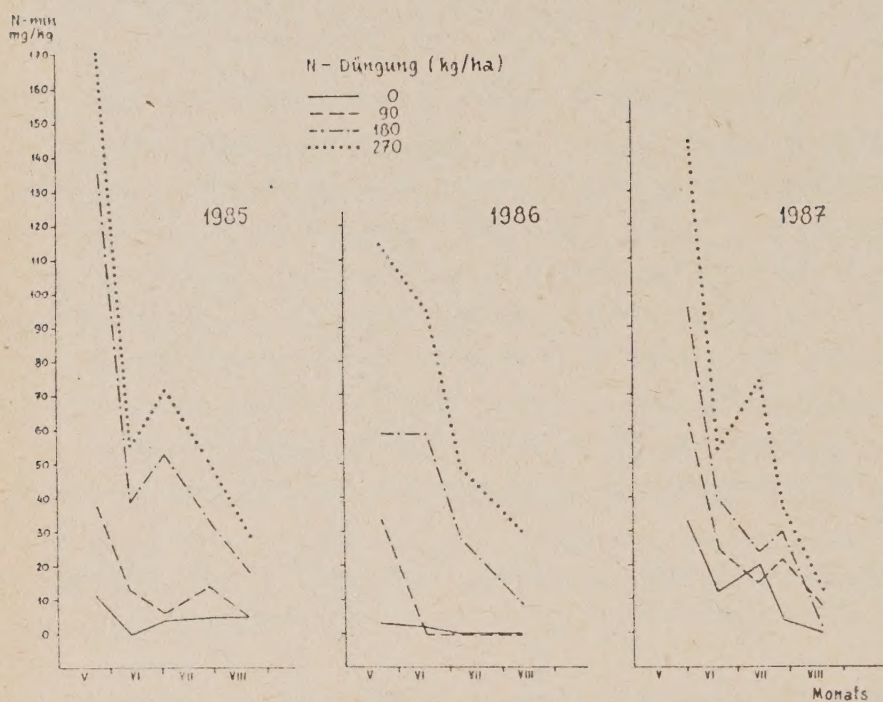


Abb. 1. N - min. Gehalt in Boden.

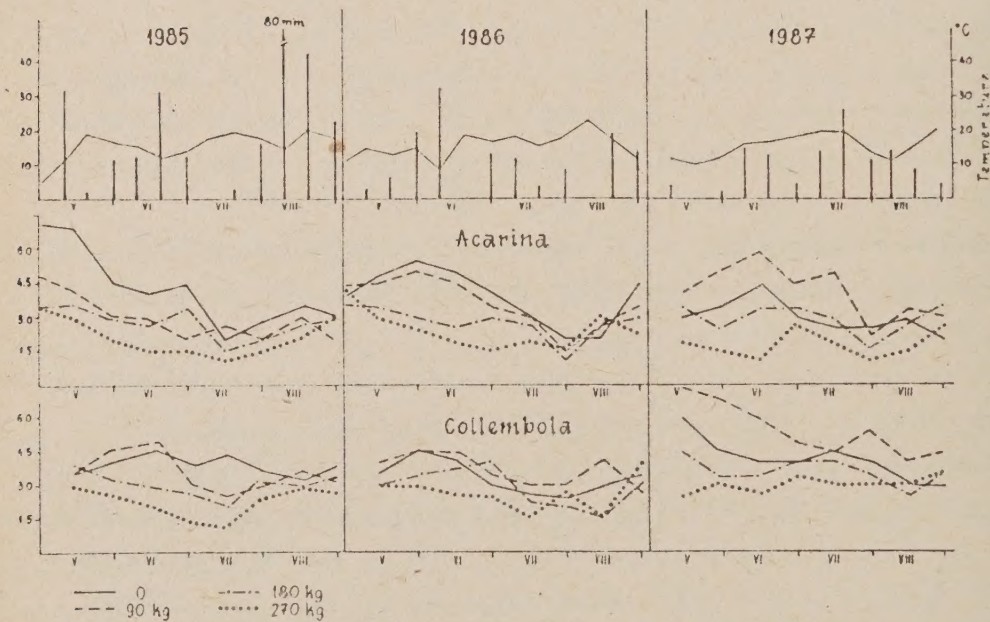


Abb. 2. Wetterverhältnisse und Collembola und Acarina Dynamik.

Das Problem der Nebenwirkung der Mineraldünger auf die Bodenorganismen ist noch wenig bekannt. Dennoch wenn man berücksichtigt wie wichtig die saprophagen Organismen für die mechanische Zerteilung der organischen Stoffe sind, und dass sie die Entwicklung der Bodenmikroflora stimulieren welche bei der biochemischen Zersetzung der organischen Überreste beteiligt ist, dann muss man befürchten, dass die Verringerung der Acarina - und Collembola fauna, als Folge grosser Stickstoffgaben, zur Hemmung der Zersetzungs Vorgänge im Boden führen muss. Das kann den Stoffumlauf und Energiedurchfluss verlangsamen und, in der Konsequenz, die Produktivität des Bodens begrenzen.

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The structure of collembolan communities under different types of recultivation of technogenic landscapes of Siberia

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The rate of development of collembolan communities during successional stages on coal mine spoils of various ages (0.5-25 yr) was studied. The investigated sites were located in the mountain-taiga, forest-steppe and steppe zones of the Kuznetsk coal mining region (KR) and in the forest-steppe zone of Nasarovskaja hollow of the Kansk-Achinsk coal mining region (KAR). In KR steppe zone the spoils were either reclaimed by planting bushes and trees (Hypophoe rhamnoides, Pinus sylvestris, Betula pubescens) or left to undergo natural revegetation of meadow and forest type in the forest-steppe or taiga zones respectively. Some of the coal mine spoils in KAR were secondary levelled and reclaimed by adding 15-25 cm of Chernozemic topsoil.

As in other regions, the microarthropods complex develops more quicker than a group of larger destructors during the technogenic succession as collembolan abundance and diversity increases more intensively than that of the mites. The same phenomena were observed by DUNGER (1968), BADENKO (1978), HUTSON (1980) and others. Complex of deep-edaphic forms - Geophilomorpha - has less success than other zoophagous species in colonization of coal heaps in the steppe and forest-steppe zones of KR. It results in the reduction of predatory pressure on edaphic forms of Collembola. Formation of soil mesofauna is slowed down in KR steppe zone: Diplopoda, Lumbricidae and Enchytraeidae appear only after 7 yr of reclamation of sites. The numbers of these groups in the 18-25 yr old minesoils under more favourable moisture conditions (in the mountaintaiga and forest-steppe areas of KR) is close or even higher than that of the respective undisturbed soils (TROFIMOW et al., 1986).

Colonization by Collembola of coal mine spoils both in KR and KAR is more successful when the waste heaps are planned, levelled and planted with bushes and trees. Initial collembolan association (or the 1st pioneer one, according to DUNGER, 1968) of no more than 1 yr old spoils consists usually of 5-6 species with the density less than $1 \cdot 10^3$ ind. m^{-2} . The initial collembolan community on secondary succession is more diverse due to the presence of edaphic forms and is composed of 9-16 species. Such pioneer associations of Collembola (8 species, $3 \cdot 10^3$ ind. m^{-2}) remain constant during the first 2 yr of development in the mountain-taiga area due to the more extreme environmental conditions.

The composition of pioneer collembolan associations is not stable and significantly varies in seasons and regions. In KR steppe zone some agrocoenose dwellers (Ceratophysella succinea, Pseudosinella octopunctata) as well as some xerophilic forms from open landscapes that later disappear from communities (Folsomides angularis, Anurophorus stepposus sp. n. and others) are present in the initial associations.

The second stage of spoil colonization is characterized by sharp increase of collembolan density (a mean value of $160 - 200 \cdot 10^3$ ind. m^{-2}) conditioned only by 1-2 species (2nd pioneer association according to DUNGER, 1968). C. succinea may be referred to the species with r-live strategy, having high indices of dominance (up to 97 %) and high frequency of occurrence.

BOHÁČ J., RŮŽIČKA V. (eds.), 1989: Proc. Vth Int. Conf. Bioindicators Deteriorationis Regionis. Institute of Landscape Ecology CAS, České Budějovice, pp. 126-129.

The same strategy is demonstrated by Hypogastrura manubrialis during the secondary successional changes without adding chernozemic top-soil. The indices of dominance of these litter forms sharply decreased with increasing developmental age, being not more than 1-8 % and 48 % in the forest and meadow undisturbed ecosystems respectively. Usually there is no or very few litter-edaphic forms of Collembola just at the beginning of succession. The indices of dominance of Mesaphorura krausbaueri, Isotoma notabilis, Cryptopygus cf. sphagneticola and species of genus Folsomia increase only on 11-25 yr old spoils, when the environmental conditions become more favourable.

Collembolan communities of young and middle-aged spoils of KAR and KR have extremely uneven spatial distribution dependent on nano- and microrelief and the structure of grass cover. Soils of the summits and backslopes of sloping spoils are more densely inhabited by Collembola as well as soil under plants with radical rosettes such as Trifolium, Achillea, Sisymbrium, Tussilago. Sites without vegetative cover are slowly colonized. The increasing part of collembolan community begins to concentrate under the crowns of Hyppophoe rhamnoides and Pinus sylvestris as litter forms 3-6 yr after reclamation, while the concentrative function of the ruderal vegetation reduced. In the more extreme environment of mountain-taiga zone one can find collembolan associations with high population density ($154 \cdot 10^3$ ind. $\cdot m^{-2}$) dominated by Hypogastruridae on the summits of the heaps under ruderal pioneer vegetation after 8 yr of successional development whereas on the backslopes covered with Equisetum silvaticum collembolan communities are characterized by the dominance of the forest litter-edaphic and edaphic forms of Isotomidae and Onychiuridae.

On the partly planned sites the abundance of Collembola sharply decreases in all minesoils after 10-14 and more years of development by their diversity continues to extend. The decrease is more pronounced in KR steppe zone. In summer the population density of 10-12 yr old sites with the forest of willows and birches appeared as a result of natural revegetation achieves $2 - 7 \cdot 10^3$ ind. $\cdot m^{-2}$. The decrease is less obvious in KR forest-steppe zone on the 25 yr old sites with meadow vegetation - up to $6 - 34 \cdot 10^3$ ind. $\cdot m^{-2}$ and in the mountain-taiga zone on the 18 yr old spoil covered with willows and birches up to $19.2 - 50.8 \cdot 10^3$ ind. $\cdot m^{-2}$. The numbers of Collembola in the range of zonal soils increases with the increase of annual precipitation: in the meadow steppe it is no more than $20 - 27 \cdot 10^3$ ind. $\cdot m^{-2}$, ranges between $18.4 - 69 \cdot 10^3$ ind. $\cdot m^{-2}$ in the dark-grey forest soil of the forest-steppe zone and reaches its maximum in the mountain taiga one. Here the parcel structure of collembolan associations is quite obvious: the populations on the sites with tall grasses and herbs are more abundant (up to $95 - 106 \cdot 10^3$ ind. $\cdot m^{-2}$ in 0-30 cm layer). The collembolan density of Abies sibirica under crowns is significantly lower reaching only $19.5 - 21.6 \cdot 10^3$ ind. $\cdot m^{-2}$ but there occurs a number of forms that appear to be rather cold-loving (Appendisotoma sibirica sp. n., Proisotoma beckeri) and slowly colonizing mine spoils.

Species diversity of Collembola is maximal in the undisturbed forest soils (34-40 species). The similarity between collembolan communities of 18-25 yr old spoils and undisturbed soils is rather high (45-80 %). However some species with low density but typical for the undisturbed soils slow penetrate into the spoil substrates. In particular it can be applied to such species as A. sibirica, Pr. beckeri, Pr. sajanica, Kalaphorura cf. bermani, Supraphorura martynovae, Hypogastrura sp. in mountain-taiga zone. In steppe one such species as Xenylla maritima,

Isotomiella minor, Folsomia pseudodiplophthalma that are typical for birch forest and Micranurida pygmaea, Sphaeridia punilis from meadow-steppe ecosystems were not recorded on 0.5-12 yr old mine spoils. On the contrary, taiga middle-aged minesoils are inhabited by a number of more thermophilic species: Isotoma olivacea (ecomorphic forms), Granuliphorura ghilarovi, Poutnana sp. which are not practically observed in the adjacent undisturbed soils.

The pattern of Collembola distribution in soil profile is an important index of the maturity of communities. Under favourable moisture conditions the main part of collembolan population on reclaimed sites occupies 0-15 cm layer with its maximum in the uppermost layer, only 2-6 % of Collembola can penetrate as deep as 30 cm. On the first 1.5 yr spoil in general larvae of Succinea migrate into the soil. The share of typical edaphic forms from such genera as Folsomia, Mesaphorura, Onychiurus, Arrhopalites increases in low soil layers especially under bushes or trees with increasing developmental time of spoils up to 3-6 yr. During dry summer periods on the summits of 8 yr. old mine spoils in the mountain taiga and KAR Collembola migrate deeper into the soil and the upper layer of 0-5 cm becomes inhabited only by 30-40 % of their numbers.

Zonal pattern of collembolan profile distribution differs from that of mine spoils by more deep penetration into soil. They are also characterized by two maximums (0-10 and 25-50 cm), the abundance of the second one due to Tullbergiinae.

In the forest-steppe zone of KAR meadow-steppe associations with very low density of Collembola of $4.77 - 17.36 \cdot 10^3 \text{ ind. m}^{-2}$ (21 species) are developed on 25 yr old sites. Secondary revegetating minesoil without adding chernozem (2 yr old) has maximal density of Collembola ($135 - 199 \cdot 10^3 \text{ ind. m}^{-2}$) and diversity of 17 species in the sites with Melilotus albus dominance (STEBAEVA, 1987).

In general Siberian coal mine wastes contain less waterloving forms of Entomobryidae (Drepasura species are typical) than European ones, Orchesellidae being absolutely absent. Hypogastruridae species more exactly indicate the beginning of the intensive colonization of coal mine wastes by Collembola. The presence of Tomoceridae, density increase of Isotoma notabilis, Folsomia and Cryptopygus species, the substitution of M. krausbaueri by the more water-loving M. sylvatica, G. ghilarovi - all these indicate the forest type of successional changes. The meadow type one can be distinguished by increasing contribution of euedaphic forms, at first due to the O. (Paronychiurus) cf. variabilis and then due to O. (Protaphorura) spp., Metaphorura bipartita, Folsomia gr. brevifurca - all these alongside with introduction of some species of Proisotoma, Anurida, Symphyleona.

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Some pedobiont biodynamic changes affected by surfactant soil pollution

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Detergents get into the soil by various ways and at different proportions. Technological processes, sewage, fertilizers, chemical weed-killers containing detergents can be responsible for pollution. Detergent dispersion in the environment may affect ecosystem functioning. Therefore it is necessary to study detergent effect upon all ecosystem components.

Collembola are one of the most numerous and widely spread groups of soil invertebrates. They play an important role in decaying processes of soil organic matter.

The effect of non-ionic AF-14 neonol detergent on the Collembola population was studied. The experimental series were held on the 1 m x 2 m grounds. The latter were placed on the peat soil on the field with perennial herbs. Test grounds were watered by 10 l of AF-14 detergent aqueous solution. 5 g/m² dose was carried into each ground. Control grounds were watered by 10 l of water without detergents. The selection of samples for analysis was made twice. The first one - in 2 days after the detergent were put into the soil. The second - in a month after the samples were treated. Traditional soil zoology methods were used in Collembola studies.

In a month there wasn't any noticeable decrease in the total number of Collembola, yet, a structural reconstruction of their community was taking place (Tab. 1). The number of typically soil (euedaphic) samples increased considerably. The number of Mesaphorura krausbaueri - very fastidious to the environmental conditions species - was reduced by 10 times. On the experimental sites the density of this species was only 3.7 % from the total number of Collembola with comparison 29.8 % on the control ones. Affected by detergent the number of surface habitat species Isotoma viridis in particular increased.

The experiments were held not only in nature, but in lab conditions as well. 20-1317-12 and OP-10 neonol non-ionic detergent effect upon 6 Collembola species: Onychiurus stachianus, Protophthora furcifera, Folsomia candida, F. fimetaria, Tomocerus minutus, Arrhopalites sp. was studied in the lab experiment.

Dried and 1 mm diameter sieve sifted soil was used as substratum. It allowed to make experimental conditions close to natural ones and to eliminate Collembola extra feeding during the experiment, as they can survive and reproduce in the moistured soil (in Petri dishes) without any extra feeding for a long time.

10 g of dry soil was put into Petri dishes. When it was watered a rather thin yet hard layer was formed. On this layer surface Collembola can survive for a rather long time without getting deeper into the soil. It quite easily allows to make measurements and calculations. 20 mg/g, 2.0 mg/g and 0.2 mg/g doses effect was studied at two humidity rates. In each variant the control over their number was taken in 1, 2, 3 and 24 hours and then on the 2nd, 3rd, 4th, 6th, 9th, 12th, 15th, 18th and 25th days since the detergent was carried into the soil. In all the test variants 5 Petri dishes were used for each species with 10 samples in each.

The experimental data proved that Collembola could easily tolerate 0.2 mg/g detergent soil concentration. In these variants no Collembola death was observed. The experiments on F. candida

Tab. 1. Collembola population changes (of different families and dominat species) affected by AF-14 neonol.

Collembola	Control		Surfactant treatment	
	number (thousand ex/m ²)	% of total number	number (thousand ex/m ²)	% of total number
Sminthuridae	2.6	7.2	5.1	15.8
Isotonidae	19.6	54.0	24.7	76.7
Onychiuridae	12.9	35.5	2.3	7.2
Hypogasturidae	0.7	1.9	-	-
Brachystomeiidae	0.5	1.4	0.1	0.3
Total :	36.3	100	32.2	100
M. krausbaueri	10.8	29.8	1.2	3.7
I. viridis	9.1	25.1	19.2	59.6
I. notabilis	5.5	15.2	4.3	13.4

showed that new generation specimens were reproduced on the 9th day since the start of the experiment both on test and control grounds.

At 2.0 mg/g detergent concentration rate 8 % of F. candida died during the first day, then their number became stable. At the same detergent concentration rate the number of the other Collembola species: O. stachianus continuously decreased and on the 18th day 52 % of the experimental specimens died.

At 20 mg/g detergent concentration of the soil soon after the experiment started, most of Collembola ceased to move actively. Movements acquired nontypical character and they lacked their reacting ability to the mechanical effect. 100 % death of different species at high humidity rate was observed on the 6th - 18th days since the experiment started. High detergent concentrations caused the death of eggs. The Collembola showed antennae damage and slime, "burnt" brown spots on the abdominal segments and tibiotarsus.

The microscopic algae are a part of soil population. They directly and indirectly interact with Collembola.

Experiments held in natural conditions show that AF-14 12.5 g/m² detergent concentration caused the soil algae number increase. Its effect remained for a rather continuous period. On the 70th day since the experiment started the number of soil alga cells on the control grounds was 21 000 and in the detergents variants - 108 000 cells in 1 g of dry soil.

The detergent concentration increase up to 125 g/m² caused the soil alga population decrease by 6 - 15 times. The population number reproduction occurred on the 8 - 10th days.

The soil detergent pollution causes the change of the character of the biodynamic processes and the structure of Collembola communities and microscopic soil algae. The character and degree of the changes depend on the type of a detergent and its dose.

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Hornmilben der Salzböden Westsibiriens

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Im Süden Westsibiriens sind Salzböden weit verbreitet. Sie befinden sich hauptsächlich in den Depressionen von Seen. Auf erhöhten Streifen lagern südliche Schwarzerden, welche z. Z. umgeackert sind. Sehr stark ausgedrückter mosaikartiger Charakter der Boden- und Pflanzendecke setzt auch die grosse Mannigfaltigkeit der Raumverbreitung von Bodenhornmilben voraus.

Für den Süden Sibiriens ist eine zyklische Entwicklung der Naturprozesse charakteristisch, was durch Pulsationen der atmosphärischen Feuchte (der Niederschläge) verursacht ist. Unsere Beobachtungen wurden während einer langjährigen, von allem regressiven Phase der Entwicklung der atmosphärischen Feuchte (1979 bis 1984) gemacht. Das Ziel der Untersuchung bestand die Artzusammensetzung, die dominierende Struktur der Oribatiden und deren Dynamik in Böden mit verschiedenem Grad der Salzhaltigkeit aufzuklären.

Es wurden 5 verschiedene Typen von Salzböden in Nordkulunda untersucht. Diese Salzbödentypen stellen eine ökologische Reihe mit allmählicher Niederung des Reliefs und ansteigender Salzhaltigkeit dar. Das sind Wiesensteppensolontsy mit Wermut- und Grassteppen (1), Wiesenolontsy mit den Kräuterpflanzen (2), Wiesenolontschaki mit den Salzkraut- und Salzmeldegemeinschaften (3), Wiesenumpfsolontschaki mit Binsenwiesen darauf (4) und Wiesenumpfsolontschaki mit Salzsimse- und Salzkräuterpflanzen (5). Für die Kontrolle wurden steppische südliche Schwarzerden auf Erhöhungen mit Kräuterpflanzen- und Grassteppen untersucht (6). Unter allen Salzböden sind Wiesensteppensolontsy und Wiesenolontschaki am weitesten verbreitet.

Es wurden alles in allem 64 Oribatidenarten gefunden, da von in Schwarzböden 37 Arten. Weiter wird, je nach der Steigung der Salzhaltigkeit, die Artenvielfalt immer weniger und verringert sich von 36 bis 16 Arten. Die Anzahl der während einer schneefreien Periode vom Mai bis November registrierten ist verschieden gross. So wurden in den Wiesensteppensolontsy zwei Spitzenzeiten mit maximaler Artenvielfalt registriert: am Anfang des Saisons im Mai, und am Ende, im November. Während der heissen und trockenen Jahreszeit (in einzelnen Dekaden im Juni und Juli) sind in der Bodenprobe nur je 2 Arten zu finden. In den Wiesensteppensolontsy sind das Scutovertex sculptus Mich. und Oribatula pallida (Banks), in Wiesenolontschaki sind das Tectocepheus velatus Mich. und Punctoribates hexagonus Berl. Im Ganzen sind in Böden des ersten Typs 36 Arten und in denen des zweiten Typs 24 Arten gefunden.

Die Anzahl von Oribatiden machte in Durchschnitt 6 Tausend Ex./m² aus. Die grösste Anzahl (8 bis 9 Tausend) wurde in südlichen Schwarzerden und in Wiesenalpböden registriert, die geringste dagegen (1 bis 3 Tausend) fand man in den Wiesenumpfsolontschaken. In den Wiesensteppensolontsy war sie auch gering (3 Tausend).

Der Vergleich der Oribatidenfaunen der untersuchten Böden nach Sørensen zeigte eine ausserordentliche Eigenart von Wiesenumpfsolontschaki, wo solche Arten üblich sind, welche sonst Überfeuchte Stationen bewohnen: Hydrozetes parisiensis Grandj., Pilgalumna tenuiclava (Berl.), Astegistes pilosus (C. L. Koch) und Punctoribates sibiricus Grish. Eine grosse Ähnlichkeit (61 bis 74 %) zeigten die Wiesenpflanzengesellschaften aus Wiesenolontsy (2), Wiesenolontschaki (3) und Wiesenumpfsolontschaki (4). Die Parzellen mit steppenartiger Pflanzendecke (1,6)

zeigten eine mittelmässig ausgedrückte Ähnlichkeit (45 bis 60 %) wie untereinander, sowie auch mit den Wiesengesellschaften. Unter den für die Kräuter- und Grassteppen auf südlichen Schwarzerden eigenen Arten sind Tectocephus alatus Berl., Lichodamaeus pulcherrimus (Paoli) und Tetroribates ornatus (Schuster) besonders auszuzeichnen. Für salzhaltige steppenartige Formationen sind Psammogalumna hungarica (Selln.) und Simkinia elongata Kriv., typisch.

Nach dem Grad der Eurybiontität stellt sich besonders der Tectocephus velatus heraus, welcher oft als Monodominant in den Böden 1 bis 3 und 6 auftritt und auch in allen anderen Bodenarten üblich ist. Etwas geringer ist die Anzahl von Scutovertex sculptus. Üblich für alle untersuchten Bodenarten sind auch Oribatula pallida, Protoribates variabilis Rajski, Passalozetes africanus Willm. und Podoribates gratus (Selln.). Eine Reihe von Arten, welche auf diesen Territorien weit verbreitet sind, fehlen in den überfeuchten Böden, das sind Peloribates euroaenus Willm., Trichoribates punctatus Shald., Peloptulus gibbus Michelcic und Humerobates translamellatus Shald., d. h., der Grad der Eurybiontität ist bei ihnen nicht so gross, wie bei den vorgenannten Arten.

Es wurden die Beobachtungen der Saisonänderungen der Anzahl von Hornmilben auf zwei Parzellen durchgeführt: in der Wermut- Grassteppe (1) und der Steppe mit Salzkraut- und Salzmeldengesellschaften (3). Es wurde eine lineare Abhängigkeit der Vielzähligkeit der dominierenden Arten von der Bodenfeuchte nachgewiesen. Während eines Saisons schwankte die Feuchte in der 0 bis 5 Zentimeter dicken Bodenschicht auf der ersten Parzelle von 3 bis 26 %, und auf der zweiten Parzelle von 12 bis 46 %. Die in der Wermut- Grassteppe dominierende Art, der Scutovertex sculptus, zeigte drei Spitzenzeiten mit ansteigender Vielzahl (die grösste davor in Oktober mit 60 Ex./dm²), was in guter Übereinstimmung mit den Spitzenzeiten der Bodenfeuchte steht. Von zwei subdominierenden Arten - Trichoribates punctatus und Oribatula pallida - war die erste besonders vielzählig im Spätherbst und die zweite im Juli und August. In der Salzkraut- und Salzmeldensteppengesellschaft war Tectocephus velatus führend. Seine Spitzenzeit fiel in die 3. Dekade von Juli (mit 110 Ex./dm²), was dem höchsten Niveau der Bodenfeuchte entsprach. Die subdominierende Art Punctoribates hexagonus war offenbar im Oktober vorherrschend.

Im Ganzen, sind die Hornmilben der Salzböden Westsibiriens wie nach der Artzusammensetzung, so auch nach der Anzahl der Vertreter entsprechender Fauna der typischen nicht salzhaltigen Böden dieser Zone (südlicher Schwarzerden) sehr ähnlich. Es wurden nur 2 Arten nachgewiesen, deren Verbreitung von dem Faktor Salzhaltigkeit abhängig ist: das sind Psammogalumna hungarica und Simkinia elongata; dabei hat die Zuordnung der letzten zu der halophylen Arten eher einen diskussionen Charakter. Unter den extremen Umweltbedingungen einer offenen Steppenlandschaft hat der Faktor Feuchte eine besondere Bedeutung. Es ist daraus ersichtlich, dass alle untersuchten Böden je nach der Oribatidenfauna in 3 Gruppen eingeteilt werden können, und zwar: Steppen-, Wiesen-, und Sumpfgruppe. Die Feuchte tritt auch bei der Saisondynamik und den langjährigen Dynamik der Oribatidenpopulationen als entscheidender Faktor auf. Diese Dynamik hat sogar bei den Populationen einer Art in verschiedenen Böden einen sehr unterschiedlichen Charakter.

Das für den Süden Westsibiriens eigene Spektrum der ökologischen Bedingungen erlaubt vielen Arten von Hornmilben auch bei starken langjährigen Schwankungen der atmosphärischen Feuchte auf dem behandelten Territorium gut zu gedeihen.

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Melanism of *Oligia* moths in Finland

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INTRODUCTION

Oligia latruncula and *O. strigilis* have similar general colour pattern: fore wings of typical form have whitish outer margin with clear contrast to the dark inner part of the wings. In the normal resting position, this pale zone resembles quite well the tops of the lichen growing on the trees. In the melanic forms this white margin turns first light brown or grey and then dark brown or even black. Simultaneously, the rest of the fore wing (and the whole insect) becomes darker and more uniformly coloured. Extreme form is unicoloured black in both species. More detailed description of the forms can be found in MIKKOLA (1975). In *O. strigilis*, the ultimate black form seems to be homozygote for the melanic allele and the pale typical form is homozygote for the normal allele. Intermediate dark morph is then heterozygote - the allele causing melanic form is semidominant over the normal allele (MIKKOLA, 1980). As there is considerable variation within the 2 melanic classes, it is very probable that there exist more melanic alleles.

O. latruncula has been the main object for the study of industrial melanism in Finland since 1972-74, when it was observed, that the species has wide-spread melanism with very high frequencies (80 - 100 % melanics) in urban areas and low (10 - 30 %) in rural districts (MIKKOLA, 1975). Later in 1980-82 the city area of Helsinki and its surroundings was surveyed in detail (MIKKOLA et al., 1982) and the south-eastern part of Finland in 1985-86 (preliminary results in VAKKARI, 1987). In *O. strigilis*, melanic forms were first obtained in 2 cities only, namely Helsinki and Kotka (120 km east of Helsinki). Melanic forms in these areas are phenotypically distinct from each others (MIKKOLA, 1980).

In addition to these two species, 31 other moth species are regarded as industrial melanics in Finland, but the frequency of melanic forms is generally were low or restricted to very small areas (VAKKARI, 1987; VAKKARI, MIKKOLA, 1988).

MATERIAL AND METHODS

Random samples of *Oligia* moths have been collected mostly with sugar bait-traps, only occasionally light traps have been used as they are quite inefficient when sampling these species. Moths were classified into 3 categories ("typical", "dark", "black") following the criteria in MIKKOLA (1975). Several samples were intermixed for scoring in order to avoid subjective bias and all individuals were checked by 2 persons. In critical cases classification was done by comparing to a standard series of colour morphs. Samples are included in the melanism collection in the Zoological Museum of the University of Helsinki.

Results represented here are based on 462 samples totalling 28301 individuals of *O. latruncula* and 240 samples, 7131 individuals of *O. strigilis*. Primary data up to 1982 and exact sample locations have been published partly in MIKKOLA (1975), MIKKOLA et al. (1982), MIKKOLA (1980) and VAKKARI (1987).

Oligia latruncula

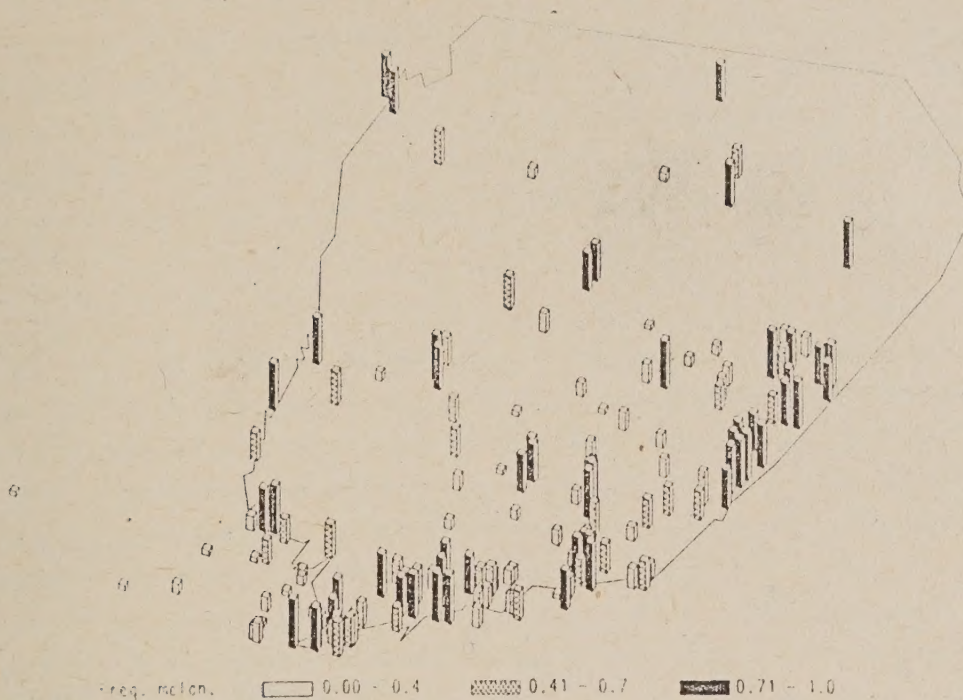


Fig. 1. Distribution of melanic forms of *Oligia latruncula* in Finland, SE-view. Each block represents mean of relative proportion of melanic forms within a 10 x 10 km square.

Oligia strigilis

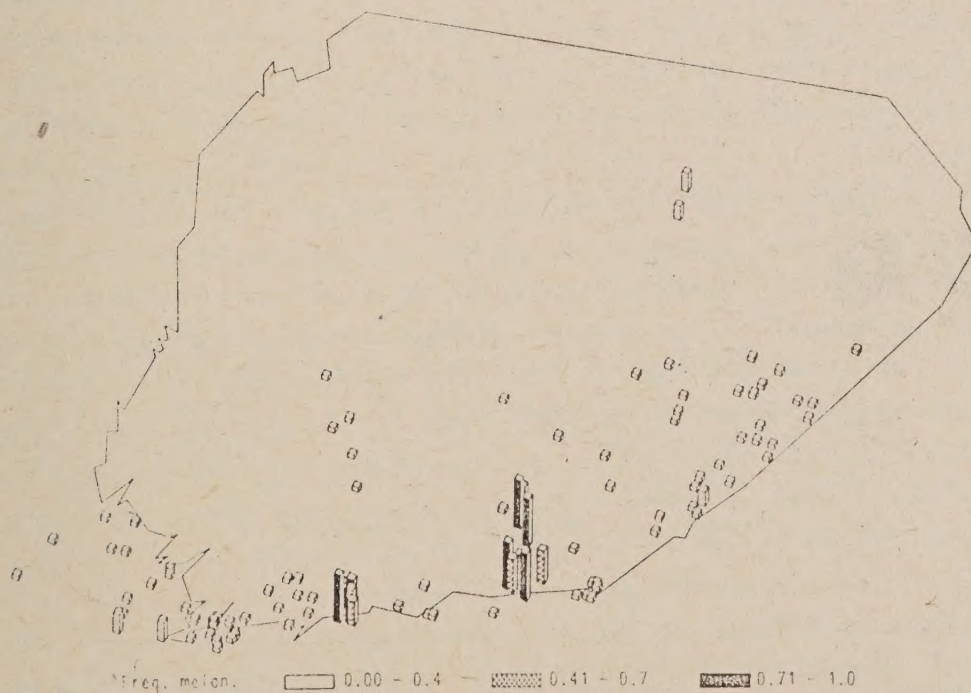


Fig. 2. Distribution of melanic forms of *Oligia strigilis* in Finland, SE-view. Each block represents mean of relative proportion of melanic forms within a 10 x 10 km square.

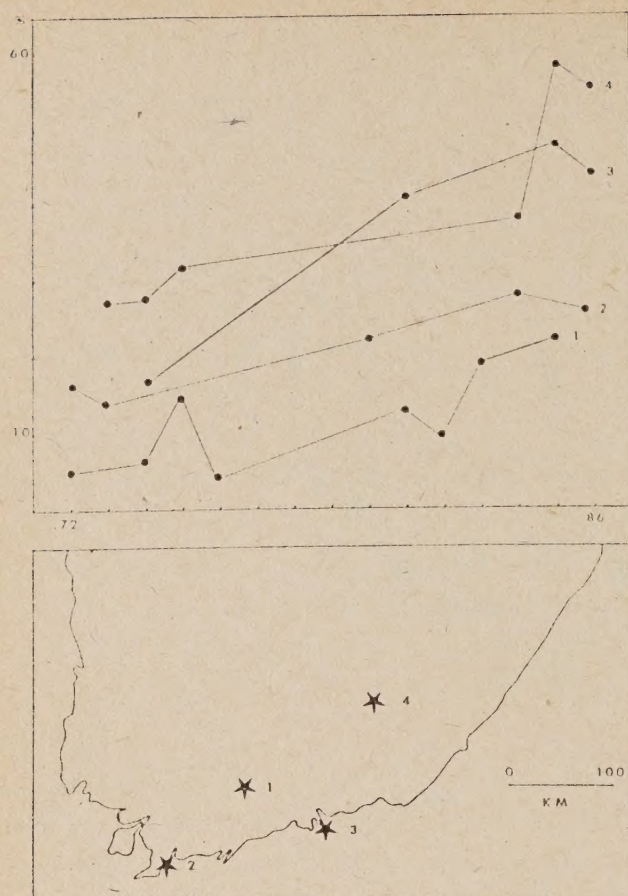


Fig. 3. Changes in the frequency of melanic forms in 4 *O. latruncula*-populations during the period 1972 - 1986. The location of the populations is given in the lower part of the figure.

RESULTS

Geographic distribution of the melanic forms is given in figures 1. and 2. for *O. latruncula* and *O. strigilis*, respectively. In these figures one block represents mean relative frequency within a 10 x 10 km square of Finnish unit grid system. The square size was chosen to demonstrate the general pattern of the distribution - much smaller size is needed for proper handling of local variation. From Fig. 1. it can be seen that the distribution of *O. latruncula*-melanics contains many details - there are many peaks at frequency of 0.8 or higher. In the middle part of the country and the south-western archipelago, the base level between the peaks is still generally well below 0.3 and a few populations (samples) have no melanics. In general, the peaks coincide with cities or industrial areas and the correlation between local SO_2 -emissions (NÖRDLUND et al., 1985) seems to be quite good, but there are 2 important exceptions: one area in the middle of the southern archipelago and the other in the south-eastern part of the country between the Saimaa lake area and USSR border. In the archipelago, high frequencies of melanics have been obtained only in the outer islands and there is a very steep cline between inner and outer archipelago, a frequency change from 0.4 to 0.8 has been observed along a 3 km gradient. It is noteworthy, that frequency decreases very rapidly to the west of Hanko peninsula. The south-eastern area is considerably larger than the previously mentioned: it includes 3 cities and there is very small decrease in the frequency between these urban areas. Both these rural melanism areas are explained poorly by local or estimated longdistance SO_2 - levels.

The distribution of O. strigilis-melanics as seen in Fig. 2. is quite different: high frequencies are still restricted to 3 city areas and even the urban populations within the south-eastern melanism area of O. latruncula have a melanism frequency from 0.0 to 0.10.

The frequency of O. latruncula-melanics is continuously increasing especially in the southernmost rural populations as can be seen from the 4 time series in Fig. 3. Similar trend has been observed in 2 other rural populations, where samples have been taken in 1974 and 1986. In Helsinki city area and in the center of south-eastern melanism area the frequencies have remained fairly stable at 0.85 - 1.00 - level over the period 1972-1986.

C O N C L U S I O N S

The traditional protective colouration hypothesis is capable to explain most of the distribution of O. latruncula-melanics, in most areas the frequency correlates well with observed/estimated sulphur emissions and consequently, degree of lichen damage. On the other hand, it is also clear, that some other mechanism(s) than selective predation must exist, because:

1. Some O. strigilis-populations in Helsinki have consistent frequency differences, which cannot be explained by either background colouration or gene flow.
2. Start and increase of melanism around a new fertilizer factory (Siilinjärvi) was far too rapid to be caused by disappearing of lichens and selective predation. In this case, lichen and tree damage was observed later.
3. No lichen damage has been observed in southern archipelago, only some species differences have been documented between inner and outer parts.

At the present level of information, 2 hypothesis seem to be worth of further investigations: direct effect of air pollutants at larval stage, especially in the early spring, and more complicated interaction between pollutants, soil, larval food plants and moths. The latter one could be a better one to predict observed sharp clines, and if it holds, melanism of O. latruncula may prove to be a sensitive tool indicating coming forest symptoms.

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Melanism in Lepidoptera as indicator of landscape changes

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We speak about melanism in the cases of occurrence of dark individuals in a species population. The matter is the increased production of dark pigments (first of all melanine) whose causes and synthesis have not been fully cleared up. Melanic forms of animals come into existence most often as mutations with melanism fixed genetically and usually dominant, more rarely recessive, or they are individual forms arising under influence of external factors (e. g. temperature and food) during ontogenesis.

Dark forms have been observed since long ago but this phenomenon attracted more attention only in the last century when the connection of the frequency of melanic forms in Lepidoptera with the development of industry and its consequences was noticed. E. g. an increased occurrence of Biston betularia L. f. carbonaria has been observed in England since the mid-19th century and this form prevailed that of typica after some 50 years. A similar trend was observed also in Western and Central Europe with a delay of some 20 years. The melanic form fully replaced the original typical one on some places. This type of melanism connected with emissions from industrial plants (first of all SO₂) is usually called industrial melanism and changes in its frequency can be used as an indicator of environmental changes. Besides this, another type is referred as rural melanism. This can be a more general reaction on global changes (e. g. global increasing of temperature, content of CO₂, perhaps also permeability of the atmosphere for cosmic radiation etc.). The nature of the rural melanism is evidently more complex. It need not follow strictly industrial regions and its indicative value will be low.

Some factors accompanying the deterioration of the environment are evidently mutagenous, moreover they form a permanent selection pressure that evokes an adequate reaction in organisms and influences evolution of populations of many species, one of its expressions being melanism.

The frequency of melanic forms rises in sensitive species under continuous selection pressure (the mutants occur more frequently and prevail in the end manifesting their advantages) and moreover melanic forms occur successively in other species where they have not been observed at all or very rarely. We can explain it in that way that heredity of these "tough" species was made shaky in the end under the influence of certain environmental factors.

In the species B. betularia where the industrial melanism was noticed in 1848 for the first time it would seem, following some interpretations (e. g. CLEVE, 1970), that melanic forms spread from west to east. It seems more probable that dark mutations occurred independently in separated regions under influence of the same or similar environmental factors (SCHUMMER, 1976). The evidence for this opinion can be that melanic forms were always discovered on the places influenced by industry and its emissions. In the case of migrations or continuous spreading they must have occurred on indifferent habitats, too. As to B. betularia, it is very mobile and we can presume its fluctuations in a landscape, but no evidence was given for its long-distance migrations. The maps must be interpreted as spreading of the phenomenon of melanism, not of the population of B. betularia f. carbonaria.

If the selection pressure ceases, the frequency of melanism can diminish as in the case of Great Britain after some measures for restriction of industrial emissions were brought to life (ASKEW, COOK, BISHOP, 1971).

The importance of melanism for a species was discussed very often (e. g. GROSSER et al., 1986). Possible advantages can be summarised as follows:

1. Protective coloration against predators (crypsis) searching for their prey in visual way
2. Physiological advantages, i. e. metabolism of harmful chemicals
3. Genetical advantages of heterozygotes of a species for adaptation in evolution.

The role of visual predation seems to have been overemphasized till lately (cf. B. betularia in KETTLEWELL, 1973). On the other hand physiological advantages, i. e. ability of an organism to get clear of harmful chemicals or to resist their harmful action, remained underestimated. There can be no doubt about the ability of heterozygote populations and their adaptive strategies to survive, but homozygotes practically do not exist in the free nature. It can be rather spoken about more or less advantageous combinations of features of individual heterozygotes.

In Czechoslovakia the first case of melanism in B. betularia was noticed in 1907, nevertheless nobody dealt with this phenomenon in detail until the sixties of this century. The authors of this paper used their results from light-trap catches and compared the frequency of melanic forms in some Lepidoptera in 1967 - 1971. Central Bohemia (Praha) and Southern Bohemia (Šumava mountains) differed substantially not only as to the quality of environment but also as to the frequency of melanism (NOVÁK, SPITZER, 1972). In the following years until the present time the occurrence of melanic forms of all possible species has been observed and a nationwide action of monitoring of B. betularia was undertaken in 1976 - 1981.

Correlations were very convincing (NOVÁK, SPITZER, 1986). While the proportion of the melanic forms in B. betularia (and other sensitive species) reached 90 - 99 % in Prague, it did not exceed 5 % in Southern Bohemia and melanic forms were not observed on some places in Šumava mountains at all. The proportion of melanic forms in B. betularia and the moths of the genus Oligia has been growing a little in some parts of Southern Bohemia (e. g. České Budějovice) during recent years. The greatest rate of melanism was observed in Northern and North-Western Bohemia, in the region of open-cast mines, thermal power-plants and heavy industry, where the proportion of melanism equaled 100 %. More than 20-year observations allow to distinguish some interesting trends. While the frequency of melanic forms changed slightly in South Bohemia, a large growth was observed in North-Eastern Bohemia (Giant and Eagle mountains) in connection with building several thermal power-plants in the German Democratic Republic, Poland and Czechoslovakia. In Prague where a light-trap has been working since 1967, melanic forms occurred in some species known formerly from other countries (CLEVE, 1970, URBACHN, 1971, SCHUMMER, 1976, GROSSER et al., 1986), but Czechoslovakia. The commented list of species with observed melanism see Tab. 1.

As to a possibility of using melanism as a bioindicator of environmental deterioration it seems to be unquestioned and advantageous. Some moths react very sensitively and rather quickly on atmospheric changes. E. g. in Eastern Bohemia melanism in B. betularia occurred several years sooner than negative consequences on vegetation cover (first of all forests) were observed. Nevertheless, not all species with melanism are suitable for bioindication but only

Tab. 1. Melanic forms of Lepidoptera in the light-trap in Praha-Ruzyně.

1967 - 1971		1978 - 1987
■ <i>Apatele rumicis</i> L. □ <i>Cranioophora ligustri</i> F. <i>Euxoa nigricans</i> L. ○ <i>Agrotis segetum</i> Schiff. <i>Xylomiges conspicillaris</i> L. ▲ <i>Apamea monoglypha</i> Hufn. ■ <i>Apamea scolopacina</i> Esp. ○ <i>Apamea ophiogramma</i> Esp. <i>Mesapamea secalis</i> L. □ <i>Oligia strigilis</i> L. □ <i>Oligia latruncula</i> Hb. ● <i>Nonagria typhae</i> Hbg. ● <i>Nonagria dissoluta</i> Tr. <i>Panolis flammea</i> Schiff. ● <i>Bomolocha crassalis</i> F. <i>Idaea aversata</i> L. ▲ <i>Lobophora halterata</i> Hfn.	● <i>Chloroclysta citrata</i> L. □ <i>Eupithecia albipunctata</i> Hw. □ <i>Chloroclystis rectangulata</i> L. ▲ <i>Ennomos fuscantaria</i> Steph. □ <i>Biston betularia</i> L. ■ <i>Cleora cinctaria</i> Schiff. ○ <i>Alcis repandata</i> L. ○ <i>Boarmia roboraria</i> Schiff. <i>Ectropis bistortata</i> Goeze <i>Bupalus piniaria</i> L. ● <i>Odontopera bidentata</i> Cl. <i>Dasychira pudibunda</i> L. ○ <i>Lymantria monacha</i> L. <i>Hyloicus pinastri</i> L. □ <i>Tethea or</i> Schiff. □ <i>Tethea ocularis</i> L. ■ <i>Diurnea fagella</i> Schiff.	<i>Apatele alni</i> L. <i>Apatele megacephala</i> F. <i>Polia nebulosa</i> Hufn. <i>Cucullia chamomillae</i> Schiff. <i>Arenostola fluxa</i> Hb. <i>Archana sparganii</i> Esp. <i>Calocalpe cervinalis</i> Sc. <i>Campogramma bilineata</i> L. <i>Perizoma alchemillata</i> L. <i>Aethalura punctulata</i> Schiff. <i>Ennomos autumnaria</i> Wernb. <i>Agriopsis leucophaearia</i> Schiff. <i>Apocheima pilosaria</i> Hb. <i>Biston strataria</i> Hufn. <i>Polyplocia ridens</i> F.
■ - increasing percentage of melanic forms during 20 years ○ - percentage of melanic forms varies strongly in individual years ▲ - percentage of melanic forms not very high but without changes during 20 years □ - percentage of melanic forms near 100 ● - rare occurrence in the light-trap in Praha-Ruzyně		

those with industrial type of melanism. E. g. melanism in a very common moth *Apamea monoglypha* has evidently another nature, similarly as *B. betularia* f. *insularia* which is a semimelanic form of more complex heredity than f. *carbonaria*.

Lepidoptera are capable in the first place of indicating qualitative changes, less the quantitative ones. The work with numeral species of different sensitivity gives more information than the unique very sensitive species as *B. betularia* because the possibilities of a sensitive species are exhausted very soon with its melanism reaching 100 %. Thus, observations of environmental changes can be prolonged with a larger group of suitable species:

1. In regions untouched by emissions where the frequency of melanic forms has been very low up to now, the growth of melanism can be very quick in sensitive species as *B. betularia*, *C. ligustri*, *T. or*, *T. ocularis*, *E. albipunctata*, *C. rectangulata* etc. after negative environmental changes.
2. If the selection pressure of unfavorable factors continues, the proportion of melanic forms in less sensitive species increases (*O. strigilis*, *O. latruncula*, *A. scolopacina*, *Boarmia* s. l. spp., *D. fagella* etc.) and melanic forms of some other species occur (*B. strataria*, *A. pilosaria*, *A. leucophaearia*, *A. alni*, *A. megacephala*, *P. nebulosa* etc.).
3. If the environmental conditions improve, it means a reduction of emissions and environment pollution, the frequency of melanic forms diminishes (as it was observed in *B. betularia*) and/or the melanism in some species can disappear at all.
4. Spreading of emissions by meteorological factors (wind, rain) must be taken into

account because melanism occurs not only in the industrial areas but also in their traces. Thus, the differences in melanism will be observable on large enough and separated territories as are e. g. Southern and Central Bohemia, distant about one hundred kilometers from one another.

In conclusion it can be said that our knowledge of melanism makes possible to a certain degree the use of bioindicators in Lepidoptera but more detailed studies can give further prospects of this method.

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Life forms and morphogenesis of animals: the use in bioindication of the environmental quality (on example of staphylinid beetles)

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Investigation of ecological structure of biocoenoses and its changes under the influence of different factors and anthropogenous effects is important from the point of view of understanding of biological answer to man's negative influence on life environment. From this reason the working out of the life forms system of organisms is perspective as the life forms reflect characteristic properties of the biotop studied. Anthropogenous activity provokes a change of substitution of life forms in ecosystem and therefore the life forms can be used as universal bioindicators.

Life form is defined as coincident morphoecological organisation of organism group with different level of relationships in arbitrary phase of life cycle that reflects characteristic outlines of their life mode in defined ecosystem (SHAROVA, SVESHNIKOV, 1988). It is a morphological conception that shows to a complex of organism adaptations to certain ecological niche. In terms of symptoms of life forms it is possible to determine the biotopic qualification of a specimen and its main functional characteristics in an ecosystem. There exist morphological, ecological and morphoecological systems of life forms depending on that if greater importance is given to morphological or ecological site. According to the structure the life form systems are linear, parallel or hierarchic. We will show the creation of hierarchic life form system and its application in bioindication on group of staphylinid beetles that are very different from the aspect of specimen and ecology as well.

Hierarchic classification of life forms of staphylinid beetle adults has not yet been worked up to now. A. MINELLI (1978) tried to divide the life forms of European staphylinids on the base of their morphology and ecology. He determined 8 types of life forms according to their typical representatives (floricol sp., species often found on vegetation, epigeic species with daily activity, species living in decay with greater or lesser movability, geophil species, endogenic species (specialized) and in soil living species). In our opinion this division is not sufficient, as species having different nutritive requirements (e. g. phytophagous species of Bledius genus and predatory species of Medon and Quedius genera) or of different body sizes (greatest species of staphylinids of Ocypus genus and median size species of Lathrobium and Xantholinus genera) are often ranged in one group. Groups for myrmecophilic and termitophilic species, spelaeous species, species living under tree bark etc. are up to now not at all created. Therefore the given division is difficult applicable from the point of view of describing the structure of staphylinids communities of different ecosystems.

The aim of our work was to create a hierarchic system of life forms of staphylinid adults according to the method of SHAROVA (1981) and to use this system for a description of ecological structure by 155 communities of staphylinids of different ecosystem types (with different influence level of man).

Tab. 1. Life form systems of staphylinids

<u>Class - zoophages</u>	
Sub-class Epigeobios	
Groups:	Epigeobionts walking, large (Staphylinus type) Epigeobionts walking, small (Philonthus type)
Sub-class Stratobions	
Groups:	living on soil surface and in decay (Othius type) living in decay (Medon type) living in decay and under bark (Dinaraea type) botrobionts (Quedius type) troglobionts (Apteranillus type)
Sub-class Geobios	
Groups:	Geobionts running - grubbing (Phytosus type) Geobionts edaphytic (Meotica type)
Sub-class Psammocolibets	
Groups:	coastal (Stenus type) from sand dunes (Astenus type) grubbing
Sub-class Petrobios (Lesteva type)	
Sub-class Torphobios (Pachnida type)	
Sub-class Sphangnobios (Gymnusa type)	
Sub-class Fytobios (Oligota type)	
<u>Class Phytophages</u>	
Group:	Dendrochortobionts (Eusphalerum type) coastal (Bledius type)
<u>Class Saprophages</u>	
Group:	living in decay and soil (Omalius type) Epigeobionts small (Oxytelus type) Troglobionts (Ancyrophorus type)
<u>Class Mycetophages (Gyrophaena type)</u>	
Group:	Symphilis (Atemeles type) Synectres (Lamprinodes type) Synoecentes (Thiasophila type)

M A T E R I A L A N D M E T H O D S

Hierarchical system of life forms of staphylinid adults was created according to the method of SHAROVA (1981). This method is based on determination of following ecological characteristics: food specialization, movement character and settlement of certain stratum in ecosystem. As morphological criteria following signs are taken in account: body forms, mandibulae, feets, sens organs builds and body sculpture and colour etc. Further the morphology and bionomics of 1000 adults of palearctic staphylinids from all taxonomic groups were investigated. During the analysis of morphological and ecological characteristics of individual groups of life forms we used the works of different authors and our proper as well (review see BOHÁČ, 1988).

Analysis of the structure of 155 communities of staphylinids from different biotops (forest, prairie and forest-prairie) with different anthropogenous influence was made on the base of determination of percentual representation of specimens found life forms in staphylinid community of given biotop.

RESULTS AND DISCUSSION

On the base of trophic specialization we divided the staphylinid adults to 5 classes of life forms (Tab. 1): zoophages, phytophages, saprophages, mycetophages and termitophils and myrmecophils. In present time the zoophages prevail at staphylinids according to trophic specialization. On the other hand significant part of species (staphylinids) is mycetophageous and saprophageous. Phytophages and myrmecophils are present in lower number. The latter mentioned groups are represented phylogenetically by groups of sub-genus Aleocharinae and more specialized families by sub-genera Omaliinae and Oxytelinae. Staphylinids that are the members of the group of zoophages, saprophages and mycetophages belong to more primitive forms in most cases (sub-genera Micropeplinae, Thoracophorinae, Trigonurinae, Proteininae, Omaliinae).

Zoophages are living in different strata in ecosystems and are divided into various groups: epigobios (inhabitants of soil surface), stratobios (inhabitants of decay, splits and crevices in soil), geobios (inhabitants of soil), psamocolibets (inhabitants of sands), petrobios (inhabitants of stony riversides and pools), torphobios (inhabitants of coastal zones of moorlands, ponds and lakes), sphagnobios (inhabitants of peat-bogs) and phytobios (inhabitants of trees and bushes). Apart this we divided the first four sub-classes into 12 groups that are characterized on the base of ecology and ethology of adults (passage grubbing, sort of movement, preferring of certain biotop etc.).

Phytophages are represented with two groups: dendrochortobionts this means specimens living on plant blossoms and leaves, nourishing with pollen and coastal specimens nourishing with algae. The staphylinids that belong to this class are phylogenetic younger families of sub-genera Omaliinae (Eusphalerum and Anthophagus genera) and Oxytelinae (Bledius genus).

We divided Saprophages into two groups: species living in decay and soil and epigeic species living on plant residues and animal excrements. This class is represented by more primitive specimens of sub-genus Omaliinae and Oxytelinae. On the other hand we can to range have even some specimens of young sub-genus Aleocharinae (specimens of genera Atheta).

Primitive groups of staphylinids (sub-family Proteininae, Thoracophorinae, Micropeplinae) and representants of young sub-family Aleocharinae (species of genera Gyrophaena, Bolitochara, Atheta etc.).

Myrmecophils and termitophils are represented with highly specialized species of staphylinids that due to their morphology, physiology and bionomics are adapted to the life in host niduses.

At the adults of genus Aleochara we find the zoophagy (they actively catch the larvae of double-wings insect). The larvae of the 2nd and 3rd development stage of this genus are ectoparasites of double-wings pupariae). Each of separated groups can be morphologically a ecologically characterized (BOHÁČ, 1988).

The investigation of life form spectrum of staphylinids in communities of 155 biotops showed that the number of life forms changes from 4 (sandlands) to 11 (cultivated meadows). The greatest variety of life forms was found in staphylinids communities living in natural or seminatural ecosystems (forest, prairie, climax woods, not regulated riversides and brooksides, subalps meadows, pondboards). For each of ecosystems the predomination of specimen exemplars of certain life forms is characteristic. In natural forest ecosystems with thick decay layer zoophages predominated represented by stratobionts living simultaneously on the soil surface

and in decay or only in decay. The exception is made by mount forests with fir where the zoophages-geobionts prevailed, living in deep soil and a thick decay layer and forests on broken stones where zoophages-epigeobionts prevailed both, small and big. In cultivated pin woods with relatively thick decay layer there lived mainly the zoophages represented by stratobionts from the group living on soil surface and in decay. In cultivated spruce woods where the decay layer is relatively thin the walking epigeobionts with small body sizes prevailed.

Spectrum of life forms of staphylinid adults specifies ecological and anthropogenous factors in ecosystems of open landscape. In peat-bogs and moorlands the sphagmobionts and torphobionts prevail but their number substantially decreases on sites of peat winning and sites of moorland draining. In sandbanks there prevail among the staphylinids the psammocolibets from species living in dunes. On riversides and brooksides there prevail zoophages represented mainly by grubbing gebionts and coastal psammocolibets. Regulation of watersides leads to a decrease of their number and to increase of the group part of small walking epigeobionts. Similar changes in life form spectrum of staphylinids were observed at scraping of pondsides where primary predominating group of grubbing zoophages - geobionts was after scraping substituted by small walking zoophages - epigeobionts. In agrocenoses, on pastures, where the decay layer is weekly developed there prevailed zoophages - epigeobionts walking small and big and stratobionts living on soil surface and in decay.

In certain staphylinids communities there can also be numerous even other classes of life forms of adults than zoophages. High portion of mycetophages was found in beech woods that of saprophages in cultivated meadows and pastures. This can be explained by number of cow-excrements on pastures or by application of natural manure on the meadows.

In conclusion we can say that the analysis of spectrum of life forms of staphylinid adults in their communities well specifies the structure of their communities and their changes under the man's influence.

C O N C L U S I O N

A hierarchic system of life forms of palearctic staphylinids adults is proposed that was used for the analysis of 155 communities of staphylinids from various biotops with different anthropogenous influence. Frequency changes of some life forms of staphylinids in communities of biotops influenced by man were found.

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Bionomic strategies of Lepidoptera and their bioindicator value

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The theory of r- and K-selection strategies was formulated by MacARTHUR et WILSON (1967) and further elaborated by PIANKA (1970) and SOUTHWOOD (1977). In spite of recent criticism, r- and K-selection dichotomy (STEARNS, 1976; PARRY, 1981; BOYCE, 1984) remains a useful concept in contemporary ecology (SOUTHWOOD, 1977; SPITZER et al., 1984; PUTMAN, WRATTEN, 1984; BARBAULT, 1987; SPITZER, LEPŠ, 1988).

The main idea of the theory is well empirically based: Species with high natality (and often high mortality) and some other typical features of their population ecology, namely dispersal capability and high population abundance variation, are able to colonize various disturbed, temporary and anthropogenic habitats (e. g. ruderals and agro-ecosystems). Species of this type are ecologically "opportunistic" and they are called r-strategists with respect to the high value of r-parameter of logistic equation. On the other hand K-strategists are strongly controlled by the carrying capacity of environment (K), their life cycle is much longer and the natality-mortality turnover is lower than in the case of r-strategy. The K-strategists are characteristic constant species of mature ecosystems (near climax phase) and occur relatively rarely in temporary or disturbed habitats - see SPITZER et LEPŠ (1988).

The high year to year oscillation (population abundance variation) expressed as coefficient of variation (cv) should be one of the main characteristics associated with r-strategy. The coefficient of variation correlates significantly with the potential population growth rate (SPITZER et al., 1984; SPITZER, LEPŠ, 1988). A comparative study of coefficient of variation of insect population fluctuations might reflect an approximate position of a species in r-K continuum within a taxonomic group associated with a particular ecosystem (habitat).

Our studies use results of a long term census of noctuid moths (Noctuidae, Lepidoptera) carried out using light traps nightly over periods from 6 to 15 years. The light traps have been situated in three ecosystems in southern Bohemia differing in their successional characteristics and degree of disturbance (REJMÁNEK, SPITZER, 1982; SPITZER et al., 1984; SPITZER, LEPŠ, 1988). The stenotopic noctuid moths (K-strategists) associated with more or less constant ecosystems (mesic and wet grasslands, alder carrs etc.) express relatively very low values of cv (0.3 to 0.7) and low values of potential population growth rate (PGR). The characteristic r-strategists of Noctuidae associated with ruderal and agricultural vegetation reach very high value of cv (0.8 to 2.1) and high value of PGR. The ordination of 145 common species of Noctuidae (REJMÁNEK, SPITZER, 1982; SPITZER, LEPŠ, 1988) shows some distinct clusters in r-K continuum reflecting habitat characteristics (succession, disturbance). Species position on r-K continuum (indicated by population abundance variation and correlated with other r-K characteristics) associated with particular ecosystems expresses a high bioindicator value. the increasing values of species population abundance variation (cv) during long term monitoring, indicate rejuvenation and disturbance of a particular ecosystem. The constant low values of cv are basic characteristics of a more constant ("stable") mature ecosystem.

r- and K-selection strategies might be the most important theoretical ecological principle of bioindication based on long term monitoring of species diversity and abundance.

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Struktur- und Stabilitätsveränderungen in Lepidopterenzöosen als Indikator anthropogener Massnahmen

N. GROSSER

Im Bestreben, Monitoring-Systeme zur Umweltüberwachung aufzubauen, sind Lepidopteren bereits vielfach auf ihre Eignung als Bioindikatoren untersucht worden. So kann der sogenannte "Industriemelanismus" als adaptive Antwort morphologisch-physiologischer Art auf einen Faktorenkomplex u. a. aus Immissionsbelastungen zurückgeführt werden (BISHOP, COOK, 1975; COOK, MUGGLETON, 1978; NOVÁK, SPITZER, 1986).

Die artmässige Zusammensetzung von systematischen Einheiten etwa bei den Lithosiinae, kann als Langzeitindikator der Immissionsbelastung in unterschiedlich belasteten Zonen eines zusammenhängenden Gebietes genutzt werden (GROSSER, 1979).

Jeder Eingriff des Menschen in natürliche Lebensräume bewirkt eine Veränderung im Komplex abiotischer Faktoren, in der Energiebilanz des Ökosystems, in seiner phytosoziologischen Zusammensetzung und damit auch der Gemeinschaften konsumierender Tiere.

In unseren Untersuchungen sollen die Taxozöosen der sogenannten "Makrolepidopteren" familien in naturnahen Biotopstrukturen der Agrarlandschaft (gehölzfreie und gehölzarme Flächen) denen anthropogen geprägter Biotope, mit landwirtschaftlichen Kulturfleichen, gegenübergestellt werden und die auftretenden Unterschiede auf ihren indikativen Wert geprüft werden. Als erste zu untersuchende Grösse soll die arten- und familienmässige Zusammensetzung der Taxozöosen im Bereich der dominanten und rezedenten Arten (alle Arten = oder $> 1\%$ Dominanzanteil) diskutiert werden.

Die Anzahl der Arten mit Dominanzanteilen $>$ oder $= 1\%$ schwankt in unseren Untersuchungsflächen zwischen 14 und 32. Die Durchschnittswerte betragen in Obstanlagen 16,5 ($s = 1.7$), in Randbereichen der Agrarflächen (Ortsrandlagen/Feldränder) 19.6 ($s = 3.75$), in naturnahen Biotopen 24.62 ($s = 4.34$).

Eine gleiche Tendenz ist bei den Gesamtartenzahlen festzustellen: 100.2 ($s = 62.3$) in Obstanlagen, 122.9 ($s = 56.9$) in Randbereichen agrarischer Flächen und 204.9 ($s = 26.9$) in naturnahen Flächen.

Häufigste Art in den Obstanlagen ist Xestia c-nigrum, ein Ubiquist mit grosser Migrationsfähigkeit, in einem Fall Agrotis exclamationis, eine ebenfalls ubiquistische Art. Letztere hat gleichermassen eine Spitzenposition in der Dominanzpyramide von Biotopen unterschiedlichsten Typs mit nicht zu hohem Gehölzanteil. Dies trifft ebenso für Xestia c-nigrum zu. In den Agrarflächen sind weiterhin Mythimna pallens, Discestra frifolii (Noctuidae) und Phragmatobia fuliginosa (Arctiidae) zu nennen. Als einzige Geometride tritt Operophtera brumata in naturnahen Habitaten mit höherem Gehölzanteil auf (aber auch in Altbstbeständen extensiver Nutzung).

Einzig im Untersuchungsgebiet NSG "Porphyrlandschaft" (Le 84) tritt mit Apamea anceps eine indigene stenoöke Art auf, die den dortigen Grasfluren zuzuordnen ist.

Betrachtet man den Anteil der Häufigsten Art am Aufbau der Dominanzpyramide, so ergibt sich folgendes Bild: im Durchschnitt erreichen die häufigsten Arten in Obstanlagen 26.25 ($s = 8.6$) % Dominanzanteil, in Randbereichen der Agrarflächen 21.4 ($s = 8.9$) % und in naturnahen Biotopen

BOHÁČ J., RŮŽIČKA V. (eds.), 1989: Proc. Vth Int. Conf. Bioindicators Deteriorationis Regionis. Institute of Landscape Ecology CAS, České Budějovice, pp. 149-153.

12.38 ($s = 4.14$) %. Damit kommt eine Tendenz deutlich zum Ausdruck, die ihre Ursachen in der Strukturarmut in Kulturbiotopen bzw. der Strukturvielfalt in naturnahen Biotopen hat. Einseitiges und geringes Nischenangebot hat die Massenentwicklung weniger ubiquistischer Arten zur Folge, die auf Grund hoher ökologischer Potenz und grosser Dispersionsfähigkeit (Noctuidae) in der Lage sind, auch Biotope mit zeitweiliger Zerstörung ihrer Existenzbedingungen durch landwirtschaftliche Massnahmen zu besiedeln, bzw. in kurzen Abständen wiederzubesiedeln. Als r -Strategen mit hoher Reproduktionsrate und kurzer Entwicklungszeit gelingt ihnen auch die ständige Besiedlung von Flächen mit wiederholt unterbrochenen Sukzessionen (Biozideinsatz). Ihr Wirtspflanzenspektrum ist extrem breit (z. B. X. c-nigrum) oder die Larven leben unterirdisch im weniger gestörten Wurzelbereich der Vegetation (A. exclamationis). In naturnahen Habitaten ist das Nischenangebot grösser, das Nischenvolumen jedoch geringer, es treten Konkurrenzeffekte auf, da die nicht oder kaum gestört ablaufende Phytosukzession vielen Arten Entwicklungsmöglichkeiten bietet. Die Randbereiche der Agrarflächen (meist Lichtfallenstandorte der Pflanzenschutzämter) nehmen in dieser Beziehung eine Zwischenstellung ein, da sowohl Bereiche mit wenig gestörten Flächen als auch solche mit ständiger anthropogener Einflussnahme miteinander vernetzt sind.

Die entsprechenden Dominanzanteile für die häufigsten 5 bzw. 10 Arten unterstreichen dies eindeutig: 56.75 % ($s = 7.8$) bzw. 71.75 % ($s = 6.9$) in den Obstanlagen, 46.82 % ($s = 10.9$) bzw. 63.18 % ($s = 10.2$) in den Agrarflächenrandbereichen und 33.38 % ($s = 4.8$) bzw. 47.12 % ($s = 3.0$) in naturnahen Flächen.

Betrachten wir die Bedeutung der subrezedenten Arten in den Taxozönosen, so zeigt sich, dass ihr Anteil an der Bildung der Zönose in den naturnahen Flächen von grösserer Bedeutung ist als in den anderen Flächentypen mit anthropogener Belastung. Bei einem Dominanzanteil von 65.12 % der Dominanten und Rezedenten verbleiben für die Subrezedenten rund 35 %. Ihr Anteil kann deshalb nicht vernachlässigt werden. In dieser Gruppe finden sich oft Charakter- und Differentialarten einer Zönose. In den Randlagen der Agrarflächen beträgt der Dominanzanteil der Subrezedenten nur noch rund 23 % und in den Obstanlagen 19 %.

Sehen wir uns die Zusammensetzung der Artengruppe der Dominanten und Rezedenten in den unterschiedlichen Flächentypen an. In den Obstanlagen rekrutiert sich diese Gruppe aus insgesamt 6 Familien, den Noctuidae mit durchschnittlich 12 Arten (davon 7 Ubiquisten), den Geometridae mit durchschnittlich 1.75 Arten (davon 1.0 Ubiquisten), den Arctiidae mit durchschnittlich 1.5 Arten (davon 0.75 Ubiquisten), den Lymantriidae mit durchschnittlich 0.5 Arten (= 0.5 Ubiquisten), Lasiotampidae mit durchschnittlich 0.25 Arten und Sphingidae mit durchschnittlich 0.25 Arten. Im Mittel sind 3.75 Familien an der Bildung der Gruppe dominanter und rezedenter Arten beteiligt, wobei die Noctuidae den Hauptanteil stellen. Als einzige Familien sind Noctuidae und Geometridae immer am Aufbau dieser Gruppe beteiligt. In den Randbereichen der Agrarflächen ergibt sich folgendes Bild: 7 Familien sind am Aufbau der erwähnten Gruppe beteiligt. Dies sind: Noctuidae mit durchschnittlich 16.3 Arten (davon 9.3 Ubiquisten), Geometridae mit durchschnittlich 1.4 Arten (davon 1.0 Ubiquisten), Arctiidae mit durchschnittlich 1.4 Arten (davon 1.2 Ubiquisten), Lymantriidae mit durchschnittlich 0.2 Arten (davon 0.1 Ubiquisten), Sphingidae mit durchschnittlich 0.1 Arten, Notodontidae mit durchschnittlich 0.2 Arten (davon 0.1 Ubiquisten) und Drepanidae mit durchschnittlich 0.1 Arten (= 0.1 Ubiquisten). Auch hier ist die dominierende Rolle der Noctuiden unverkennbar. In den naturnahen Habitaten wurden

folgende Werte ermittelt: 14 Familien sind am Aufbau der Gruppe dominanter und rezedenter Arten beteiligt, das ist doppelt soviel wie in den anderen Flächen. Die durchschnittlichen Anteile der Familien ergeben sich wie folgt: Noctuidae 11.4 (davon 6 Ubiquisten), Geometridae 5.2 (davon 2.4 Ubiquisten), Arctiidae 0.9 (davon 0.2 Ubiquisten), Lymantriidae 0.1 (= 0.1 Ubiquisten), Pieridae 1.1 (davon 1.0 Ubiquisten), Satyridae 3.0 (davon 2.5 Ubiquisten), Cymatophoridae 0.1, Psychidae 0.1, Lasiocampidae 0.1, HesperIIDae 0.6, Nymphalidae 0.4 (= 0.4 Ubiquisten), Lycaenidae 0.2, Drepanidae 0.1 und Sphingidae 0.2. Der Anteil der Noctuidae geht zugunsten anderer Familien zurück, auffällig ist das Hinzutreten von Rhopalocerenfamilien, die in den anderen Flächen keine Rolle spielen und als besonders empfindlich bei anthropogenen Massnahmen gelten. Der relativ hohe Anteil von Ubiquisten in einigen Familien indiziert Randeffekte bzw. die geringe Flächenausdehnung der naturnahen Habitate.

Betrachtet man den Anteil indigener nicht ubiquistischer Arten, die stabiler Bestandteil der Zönose sind, unter den häufigsten 5 bzw. 10 Arten, so sind in den Obstanlagen 0.25 bzw. 0.75 Arten zu nennen, die der Krautschicht zuzuordnen sind, in den Randlagen der Agrarflächen 0.5 bzw. 1.1 Arten. Eine Indigenfauna im eigentlichen Sinne ist kaum ausgebildet und die Zusammensetzung dieser Gruppe dem Immigrationsdruck aus Nachbarflächen zuzuschreiben. In den naturnahen Biotopen liegen diese Zahlenwerte höher: 1.5 bzw. 4 Arten sind als immanenter Faunenbestandteil zu betrachten. Dabei sind nicht die langfristigen Schwankungen der Populationsdichte einzelner Arten berücksichtigt, so dass der Anteil dieser Arten schwanken kann bzw. diese durch andere Indigenae ersetzt werden.

Im weiteren sollen typische Formen von Dominanzpyramiden aus den einzelnen Flächennutzungstypen gezeigt werden. Als Beispiel für die Obstanlagen soll die Fläche "Neu 82" gezeigt werden (Abb. 1).

Einer Art mit hohem Anteil folgen weitere mit sehr schnell abfallenden Dominanzanteilen. Mit X. c-nigrum ist dies ein Migrant, gefolgt von L. monacha, die ebenfalls migrierend im Untersuchungszeitraum auftrat und nicht Bestandteil der Indigenfauna ist. Aus benachbarten Biotopen stammen A. fucosa, P. alchemillata, H. micacea, A. oculatea, L. testacea, die übrigen Arten können vorübergehend in der Anlage bzw. ihren Randbereichen geeignete Entwicklungsmöglichkeiten finden. Als Beispiel für die Randbereiche der Agrarflächen soll die Untersuchungsfläche "Neu 86" dienen (Abb. 2).

Arten der Ökotone mischen sich mit solchen von Feldflächen und Gärten. Die aus der Summation der Dominanzanteile resultierende Kurve weist im Anfangsteil einen flacheren Anstieg als die in Abb. 1 auf. In Abb. 3 ist die Fläche "Le 84" als Beispiel für ein naturnahes Flächenelement der Agrarlandschaft dargestellt. Der Kurvenanstieg ist flach, die Dominanzpyramide zeigt geringe Abstufungen, ein gleichmässiger Aufbau ist typisch.

Im folgenden soll der Versuch demonstriert werden, mit Hilfe eines Indigenitätskoeffizienten globale anthropogene Belastung zu indizieren. Als indigen bzw. bedingt indigen werden dabei alle Arten betrachtet, die innerhalb einer Untersuchungsfläche ihren Entwicklungszyklus realisieren können. Die folgenden Ergebnisse zeigen eine deutliche Differenzierung innerhalb der aufgestellten Flächentypen. $KI = 0.14$ für Obstanlagen charakterisiert einen extrem niedrigen Anteil indigener Arten. Bei $KI = 0.54$ für Agrarflächen liegt ebenfalls ein Übergewicht nicht indigener Arten vor, dagegen zeigt $KI = 8.9$ in naturnahen Flächen einen hohen Anteil indigener Arten. Der Anteil zufälliger Elemente der Zönosen nimmt also in der genannten Reihenfolge der Flächen ab und damit die Stabilität und Regulationsfähigkeit innerhalb der Taxozönose zu.

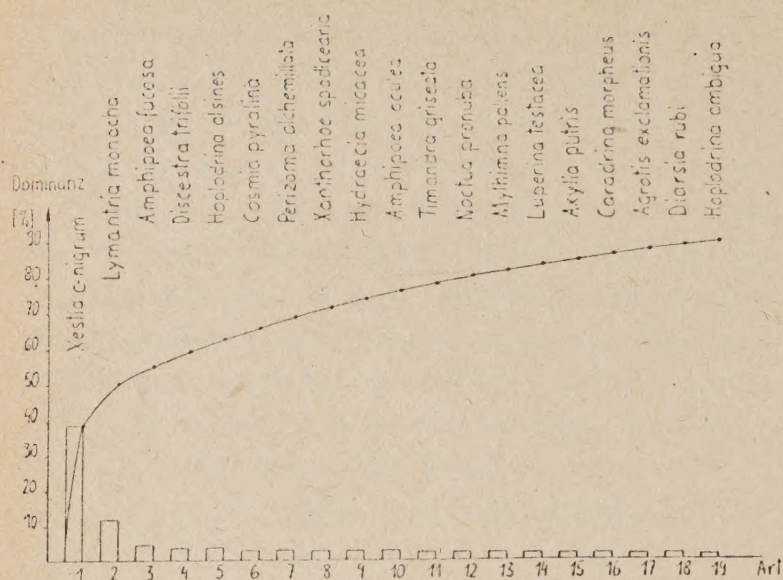


Abb. 1. Dominanzpyramide und summierte Dominanzanteile der Lepidopterentaxozönose in der Untersuchungsfläche "Neu 82".

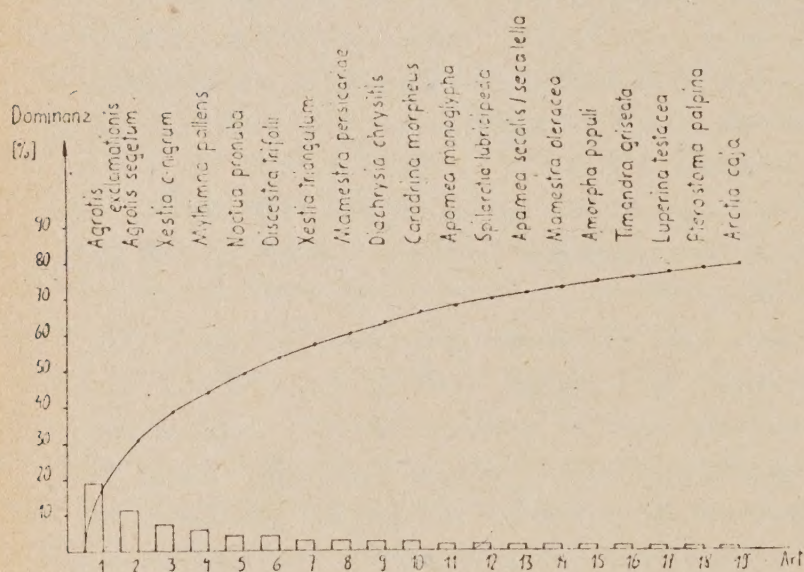


Abb. 2. Dominanzpyramide und summierte Dominanzanteile der Lepidopterentaxozönose in der Untersuchungsfläche "Neu 86".

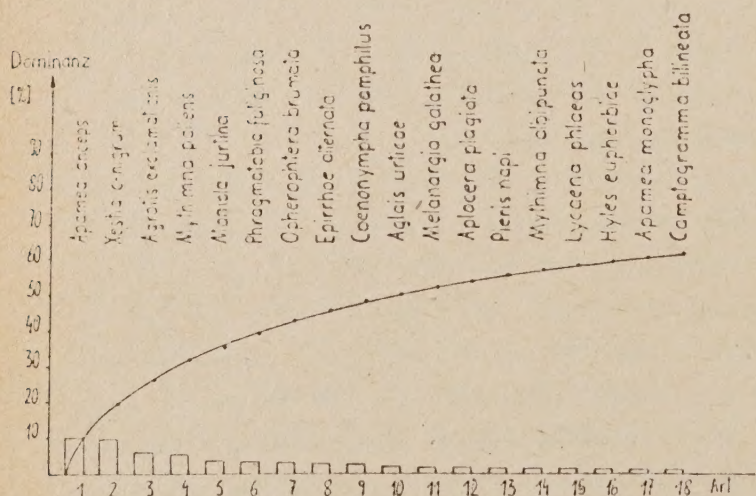


Abb. 3. Dominanzpyramide und summierte Dominanzanteile der Lepidopterentaxozönose in der Untersuchungsfläche "Le 84".

Die Nutzung von Komplexitätsmassen zur Bioindikation ist umstritten, da die absoluten Zahlenwerte wenig über die kausalen Zusammenhänge innerhalb der untersuchten Zönose aussagen. Deshalb sollen nur die Durchschnittswerte für die Flächentypen aufgezeigt werden:

	Obstanlagen	Agrarflächen Randbereiche	naturnahe Biotope
Diversität	3.13	3.38	4.16
Eveness	0.64	0.72	0.78

Die Unterschiede sind in gleicher Weise ausgeprägt wie bei den bereits betrachteten Größen und unterstreichen die höhere Komplexität der Zönose in weniger anthropogen belasteten Flächen.

Zusammenfassend kann gesagt werden, dass eine Bioindikation mit Hilfe der Analyse von Lepidopterentaxozönosen im Sinne der komplexen anthropogenen Belastung mit allen untersuchten Größen möglich ist. Aussagen lassen diese Parameter vor allem bezüglich der Qualität der Biotope im Sinne eines regulationsfähigen Systems zu. Einen wesentlichen Stellenwert besitzt die Zusammensetzung der Taxozönosen aus indigenen Elementen und solchen, die als Immigranten eine instabile Zönose aus Ubiquisten bilden.

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25-year changes in steppe spider communities in the surroundings of Lochkov at Prague

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INTRODUCTION

Within each ecological classification (hydropreference, thermopreference, etc.), the frequency of the number of species and the frequency of the number of individuals of species of a coalition in a community can be evaluated. In classifications that properly take into account ecological demands of species, the two quantities are interrelated. This interrelation was initially expressed by us as a sigmoid plot of the frequency of the number of species in dependence on the frequency of the number of individuals (RŮŽIČKA, 1985). GALLÉ (1987) interchanged the dependent and independent variables and fitted the data with a logistic curve. In our set of data for forty spider communities in non-forest territories of Bohemia and Moravia (RŮŽIČKA, 1986) we examined the dependence of the frequency of the number of individuals on the frequency of the number of species in categories of thermopreference and relictiness of species occurrence using both the logistic fit,

y = 1/(1 + ae^{-bx}),

and the sigmoid fit,

y = 0.5 + sgn f(x) · ³√|f(x)|

where

f(x) = 0.25 · ³√x - 0.125

Although the two fits gave comparable standard deviations (Tab. 1), the logistic curve approached the x-axis and the y= 1 straight line more closely, thus corresponding better to the biological sense of the curve (Fig. 1).

In well- balanced communities, the frequency of the number of individuals is related to the frequency of the number of species roughly by the logistic dependence. In communities where changes are under way, this delicate equilibrium is disturbed. Two basic trends have been established in a model approach.

Tab. 1. Parameters of the logistic (a, b) and sigmoid (c) dependences of the frequency of the number of individuals on the frequency of the number of species for the various ecological categories of species. T - thermophilous species, P - psychrophilous species, N - non-specific species, R I - relicts of Ist rank, R II - relicts of IInd rank, E - Expansive species.

	T	P	N	R I	R II	R I + II	E
a	1001	500	639	573	419	1 781	500
b	15.0	15.0	12.8	17.0	13.3	13.4	15.0
σ	0.152	0.256	0.317	0.207	0.130	0.121	0.132
c	1.00	1.94	1.00	1.29	1.13	0.93	1.32
σ	0.128	0.217	0.320	0.195	0.106	0.129	0.138

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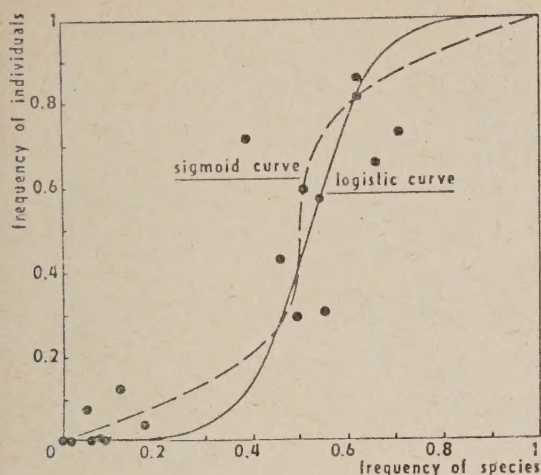


Fig. 1. Sigmoid and logistic fitting of the dependence of the frequency of the number of species for the group of thermophilous species.

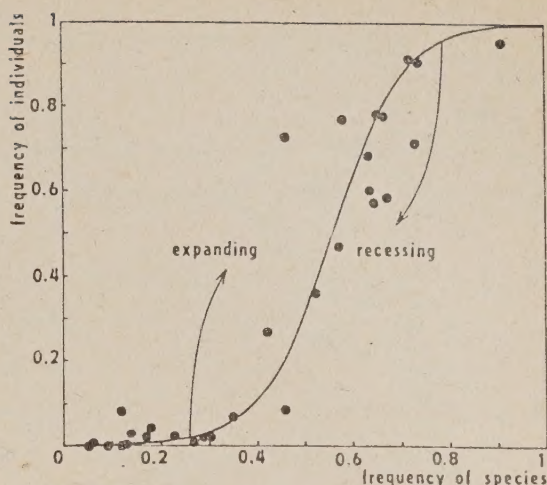


Fig. 2. A model of changes in the frequency of a group of species in the community (group of relicts of the 1st and 2nd ranks).

1. Increase in the frequency of the number of individuals with respect to the equilibrium state occurs for a group of species whose demands are in accordance with the newly establishing conditions. In the extreme case it is represented only by a few overreproduced species.
2. For a group of species whose demands correspond to the previous conditions of the habitat a decrease in the frequency of the number of individuals with respect to the equilibrium state takes place. This group can be more remainders of previously frequent populations (Fig. 2).

This hypothesis was applied to the interpretation of changes in spider communities of Limestone steppes near Lochkov.

TERRITORY, MATERIAL

The territory examined lies in the Radotin valley, about 10 km to the south of Prague. It consists of dry and warm limestone slopes hosting rich steppe flora and fauna. The area of the territory is about 10 hectares.

The first investigation of the arachnofauna was performed in the years 1960 and 1961 (VALEŠOVÁ, 1962; MILLER, VALEŠOVÁ, 1964). Eight sites were selected for picking by the pitfall trap method, viz. bare stony slopes (4, 5), slopes with sparse trees (1, 2), a heap of stones under a small rock (7), unmown meadows (3, 6) and a mown meadow (8). At the various sites, the number of spiders collected was 100-500 and they belonged to 30-50 species. The total collected was 1 405 individuals belonging to 87 species in 1960, and 1 715 individuals belonging to 97 species in 1961.

The incentive for the examination of the steppe localities in the surroundings of Lochkov was the fact that a cement factory was to begin its production in June, 1961. Since then, the entire territory would be covering with fine limestone dust. Because this cement production

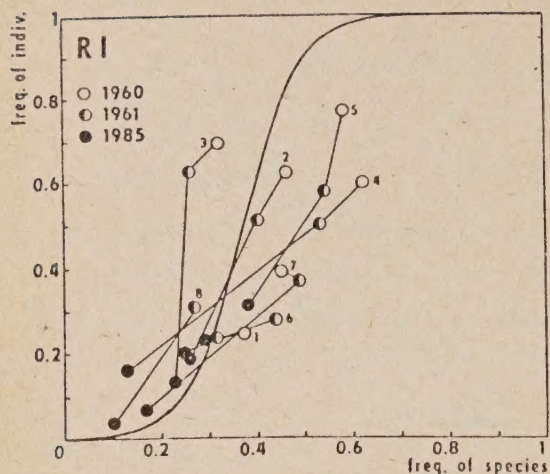


Fig. 3. Frequencies of the group of relicts of 1st rank in arachnocenoses of the sites 1-8 in 1960, 1961 and 1985.

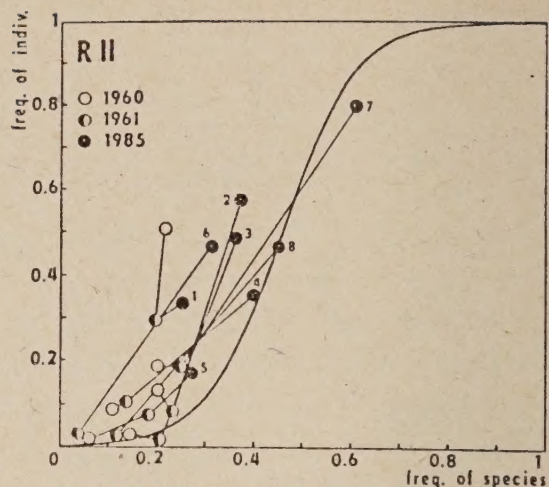


Fig. 4. Frequencies of the group of relicts of 2nd rank in arachnocenoses of the sites 1-8 in 1960, 1961 and 1985.

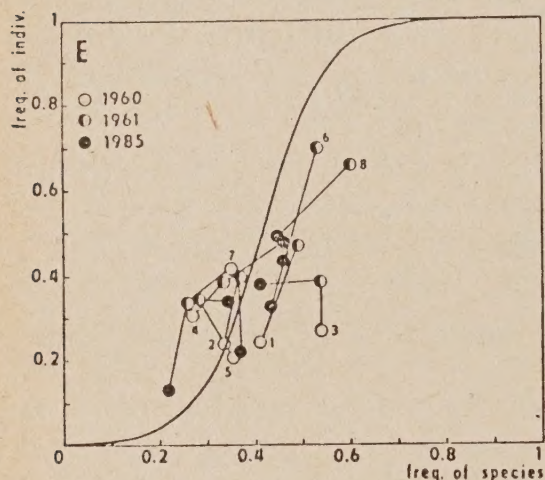


Fig. 5. Frequencies of the group of expansive species in arachnocenoses of the sites 1-8 in 1960, 1961 and 1985.

was expected to affect the flora and fauna, this first inventory was made to obtain reference data for future comparison.

In 1985, one of us (M. A.) undertook a collection examination at the same sites as Valešová had a quarter of a century before. Only sites No. 4 and 5 had remained virtually unaltered. The other sites had been grown by shrubs and trees, often due to improper planting. 40-140 spider specimens belonging to 18-37 species were collected at the various sites in 1985; the total was 580 specimens belonging to 91 species (ANTUŠ, 1986).

The species were divided into three categories: relict of the 1st rank, relicts of the 2nd rank and expansive species (BUCHAR, 1983), and changes in the communities were treated in these terms.

RESULTS

Relicts of the 1st rank

The occurrence of these species is concentrated in original biotopes minimally affected by the activity of man, such as rocky steppes, peat bogs, mountain peaks or virgin forests. They belong to the natural treasure of protected territories.

A marked decrease in the frequency of the number of individuals of these species was found at all sites of the territory examined (Fig. 3). This decrease could be disclosed as early as 1960. For the majority of sites, the points in the plot corresponding to relicts of the 1st rank lie below the logistic curve, i. e. the frequency of the number of individuals is lower than as corresponds to the frequency of the number of species in a well-balanced community. The frequency of the number of individuals of relicts of the 1st rank over the entire territory decreased from 0.55 in 1960 to 0.21 in 1985. If this trend continues, this frequency can drop to as little as 0.04 which is a value observed in forest parts of a typical steppe-forest region of the Karlštejn surroundings (BUCHAR, ŽDÁREK, 1960). The decrease in the frequency of the number of individuals is followed by a decrease in the frequency of the number of species, which implies a qualitative degradation of the communities.

Relicts of the 2nd rank

Forest species that inhabit forests with little respect to the degree of their anthropic disturbance.

Virtually at all sites, relicts of the 2nd rank occur in the ascending stage above the equilibrium logistic curve (Fig. 4). The frequency of the number of individuals has grown from 0.17 in 1960 to 0.44 in 1985. The territory has been afforesting gradually. In the forest parts of the Karlštejn steppe-forest region the frequency of the number of individuals of 2nd rank relicts is 0.79 (BUCHAR, ŽDÁREK, 1960).

Expansive species

These species are able to colonize also artificially deforested habitats; they are the predominant species on fields and meadows. The frequency of the number of individuals of expansive species thus can serve as a convenient index of anthropic disturbance of the habitat under examination. In the context of natural conditions of Bohemia, the frequency of the number of individuals of expansive species in protected territories attains a maximum value of 45 % (RŮŽIČKA, 1936).

In 1961, the frequency of the number of individuals of expansive species increased at nearly all sites; this trend, however, ceased to continue. Various changes occurred at the sites till 1985; the entire territory, however, the frequency of the number of individuals of expansive species remained virtually constant (Fig. 5), hence, the expected increase in this frequency did not take place. The spider communities are not negatively affected by the limestone fallout; perhaps, this fallout even helps to neutralize acid immissions coming from the Prague agglomeration.

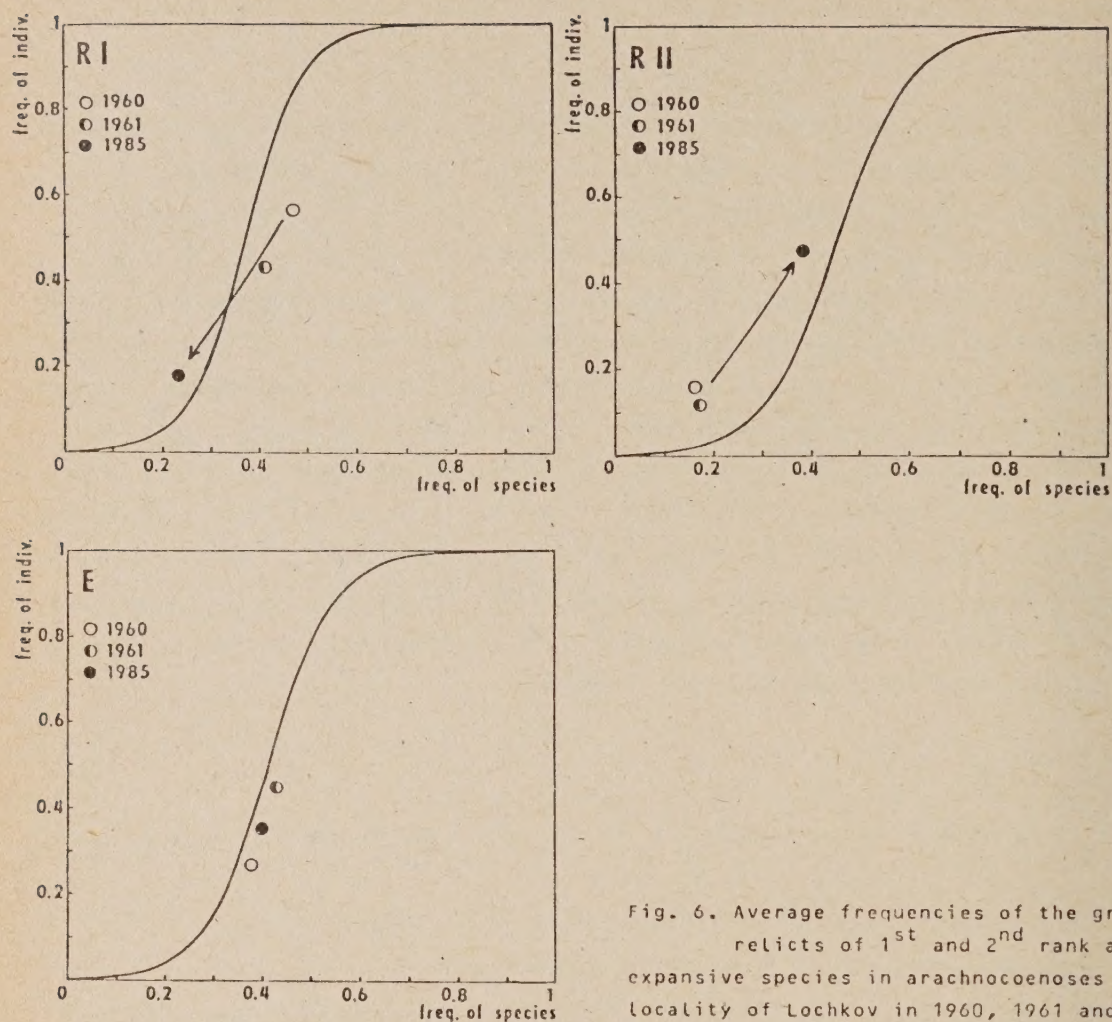


Fig. 6. Average frequencies of the groups of relicts of 1st and 2nd rank and of expansive species in arachnocoenoses of the locality of Lochkov in 1960, 1961 and 1985.

CONCLUSIONS

It was ascertained that the protected territory of the Lochkov profile is not so much endangered by production in the cement works as by the unsuitable afforestation and uncontrolled propagation of woody plants. The alarming decrease in the frequency of relict of the 1st rank should become a stimulus to nature conservancy bodies: the unwanted woody plants should be removed and, perhaps, the protected territory could be extended to the surrounding areas having the original character of a rocky steppe.

If the parameters of the logistic curve are obtained for various properties of the species, factors causing changes in the structure of the community can be disclosed based on a single collection of material, long-run monitoring being then unnecessary. In the case of afforestation of the habitat under study, the situation is clear at first glance, but in other cases it may not be so obvious. More complex information can be derived from the evaluation of a set of factors. Among the major factors participating in the formation of vegetation and animal communities will be moisture and the degree of anthropic disturbance (KLIMEŠ, 1987a).

The unweighted average of frequencies from the various sites was used by us for an overall evaluation of the territory (Fig. 6). Actually, the average weighted by the area of the sites would be more appropriate.

The results of an ecological analysis of this kind are certainly affected by many factors, often subjectively biased (KLIMEŠ, 1987b). Still, ecological analysis can undoubtedly serve as an efficient tool for helping us to understand the processes of changes in the nature. Graphical representation of the relations is also very illustrative.

The use of indicator values is rather widespread in botany (ELLENBERG, 1979). In bioindication by means of animal communities the use of qualitative data deserves more attention. It is desirable that specialists and experts in well-examined species-rich groups of animals sum up their knowledge of the ecological demands of the species and elaborate complete ecological classifications. In this manner, our knowledge, which is very rich in some respects and has accumulated over a long period of time owing to painstaking efforts of whole generations of collectors, could be vastly exploited for the evaluation of our environment.

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Die Ausnützung von Raubkäfergemeinschaften (Coleoptera, Staphylinidae) für die Indikation der Umweltqualität

J. BOHÁČ

Die Raubkäfer gehören zu den artensweise zahlreichsten Insektenfamilien. Zu den Raubkäfern gehören die Arten von verschiedensten ökologischen Ansprüchen, dessen Imagines und Larven treten zahlreich in allen Typen von Biotopen auf, häufig mit einer engen Bindung auf einige davon. Die durch den Menschen hervorgerufenen Umweltänderungen werden zur oftmaligen Ursache der Strukturänderungen ihrer Gemeinschaften (BOHÁČ, 1986; BOHÁČ, im Druck). Deswegen sind die Raubkäfer geeignete Anzeiger der anthropogenen Umweltänderungen.

Das Ziel der vorgelegten Arbeit wird der Indexentwurf zum Ausdrücken der Beeinflussungsstufe von Raubkäfergemeinschaften durch den menschlichen Einfluss.

M A T E R I A L I E N U N D M E T H O D I K

Die Bewertung von aus der ökologisch-faunistischen Forschung stammenden Materialien zur Beurteilung der betreffenden Lokalität, bzw. ihrer Beeinflussung durch menschliche Tätigkeit, erfolgt mit Hilfe verschiedenen mathematischen Indexen (ODUM, 1983). Obwohl man diese Indexen zu den Bioindikationszielen verwenden kann, sind sie nicht ganz objektive Anzeiger der Landschaftsbeschädigung (RŮŽIČKA, 1987). Sie werden auf Grund der Artens- und Exemplarzahlen in der Gemeinschaftsprobe berechnet, die ökologischen Eigenschaften der Arten, besonders ihre Empfindlichkeit zur menschlichen Tätigkeit sind jedoch nicht einbezogen.

Zur Auswertung der Standortbedingungen werden die Werte der prozentuellen Vertretung von Arten verschiedener ökologischen Gruppen verwendet. Diese Methode verwertet unsere Kenntnisse über die ökologische Ansprüche der Arten. Zur Bewertung der anthropogenen Schädigungsstufe wird die Klassifizierung der Reliktität von Arten vorkommen geeignet. Diese wurde ursprünglich für die Spinnen (BUCHAR, 1983), nachfolgend für die Raubkäfer (BOHÁČ, im Druck) ausgearbeitet, und es ist bestimmt möglich sie auch für andere Wirbellosegruppen auszuarbeiten. Die fauna unserer Raubkäfer wurde in drei Gruppen aufgeteilt: 1. die Arten mit dem Vorkommenschwerpunkt in Naturschutzgebieten und in den durch die menschliche Tätigkeit ungestörten Gebieten (die Relikten der I. Ordnung), 2. die in den künstlichen Waldökosystemen vorkommenden und in die nichtwaldliche Ökosysteme nicht eindringenden Arten (die Relikten der II. Ordnung), 3. ubiquitäre Arten mit den Vorkommenschwerpunkt in der offenen Agrarlandschaft und in den Urban-Ökosystemen (Felder, Wiesen, Ruderalstellen).

Für die Beurteilung der Deteriorisationsstufe von Standorten hat sich die Anwendung der prozentuellen Vertretung der Exemplaranzahlen von Expansionsarten bewährt. Dieser Wert nimmt von den durch den Menschen wenig beeinflussten Lokalitäten aus zu den anthropogenen Lokalitäten zu. KŮRKA (1987) hat jedoch auf die Notwendigkeit der Beurteilung aller drei Gemeinschaftskomponenten, nicht nur der einzigen Komponente, hingewiesen. Wir haben versucht einen einfachen mathematischen Index zu entwerfen, der die Vertretung aller drei Komponenten in den Gemeinschaften berücksichtigen würde. Diesen Index nennen wir als "Index der Raubkäfergemeinschaften" (staphylinid index).

BOHÁČ J., RŮŽIČKA V. (eds.), 1989: Proc. Vth Int. Conf. Bioindicators Deteriorationis Regionis. Institute of Landscape Ecology CAS, České Budějovice, pp. 160-164.

$$SI = 100 - \left(\sum_{i=1}^n U_i + 0,5 \cdot \sum_{i=1}^n R_{II} \right)$$

SI - Index der Raubkäfigergemeinschaften, U - die Summe der prozentuellen Vertretung von Exemplaranzahl der ubiquistischen Arten, R II - die Summe der prozentuellen Vertretung von Exemplaranzahl von Relikten der II. Ordnung.

Das Berechnungsbeispiel siehe Abb. 1. Der Indexwert variiert von der 0 (in der Gemeinschaft wurden nur ubiquistische Arten festgestellt, die Gemeinschaft wird stark anthropogen beeinflusst) bis 100 (in der Gemeinschaft treten nur die Relikte der I. Ordnung auf, die Gemeinschaft wird praktisch vom Menschen unbeeinflusst). Wenn wir einmal die Werte, die der Index in verschiedenen Isotopen einnimmt, feststellen, können wir dann mit einer Zahl die Stufe der anthropogenen Beeinflussung von untersuchten Gemeinschaften charakterisieren. Der problematische Vergleich mit einzelnen Kontrollen fällt ab.

Die Beziehung zwischen dem Index der Gemeinschaften des gegebenen Biotops und der Artenanzahl in den Gemeinschaften kann rückwirkend als ein Anzeiger der Empfindlichkeit einzelner Arten zur menschlichen Tätigkeit und auch zur eventuellen Korrektur der ursprünglichen Klassifizierung (Abb. 2, 3) benutzt werden. Die graphische Darstellung dieser Beziehung wurde bei 155 Gemeinschaften und 70 Raubkäfigerarten durchgeführt.

ERGEBNISSE

Der Index der Raubkäfigergemeinschaften erscheint als geeigneter Anzeiger der anthropogenen

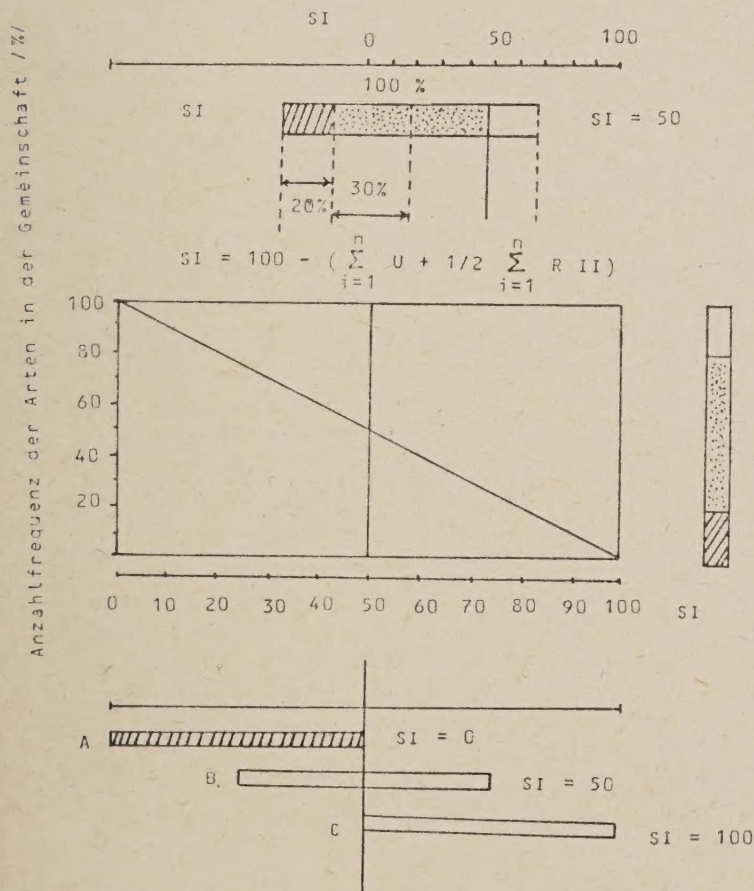


Abb. 1. Ein Beispiel der Berechnung des Indexwertes der Raubkäfigergemeinschaft (SI).

$\sum_{i=1}^n U_i$ - prozentuelle Exemplarvertretung der ubiquistischen Arten in der Gemeinschaft,

$\sum_{i=1}^n R_{II}$ - prozentuelle Vertretung der Reliktenexemplare in der Gemeinschaft.

A - nur die Ubiquisten in der Gemeinschaft,
B - nur die Relikten der II. Ordnung in der Gemeinschaft,
C - nur die Relikten der I. Ordnung in der Gemeinschaft.

Beeinflussungstufe der untersuchten Biotopen. Sein Wert wächst von den stark beeinflussten Biotopen (Ruderal. St., Agrozenosen, Viehweiden, $SI=0-10$, künstliche Waldökosysteme, $SI=0-31$) aus zu den weniger beeinflussten Biotopen (Eichen-Weissbuchenwälder, azidophile Eichenwälder, Buchenwälder, Erlenbüsche, Schuttwälder, Waldsteppe, kultivierte Wiesen, $SI=25-59$). Die höchsten Indexwerte ($28-100$) wurden für die Käfergemeinschaften in den natürlichen Gemeinschaften sich nähernden Biotopen (Waldsteppen-Eichenwälder, Gebirgswälder mit der Tanne, Ufer der unregulierten Bäche und Flüsse, Moore, Sandüberschüttungen, Salzmooren, subalpine Wiesen) festgestellt.

Nach dem Typ der Beziehung zwischen dem Raubkäfergemeinschaftenindex und der Anzahlfrequenz von Exemplaren in der Gemeinschaft haben wir die Raubkäfer in drei Gruppen aufgeteilt: anthropophile, anthropoindifferente und anthropophobe Arten.

In jeder der aufgeführten Gruppen haben wir zwei Artenuntergruppen festgestellt: die Arten mit einer hohen und mit einer niedrigen Frequenz. Diese Arten haben wir nach den Lebensstrategien und Lebensformen, nach der Zugehörigkeit zu den Grösseordnungsgruppen, nach der Thermo- und Hydropräferenz und nach der zoogeographischen Verbreitung (BOHÁČ, 1988) charakterisiert.

Die aufgeführte Auswertungsmethode der Reaktion der Arten auf die anthropogene Einflüsse ermöglicht die Reaktion aller Raubkäferarten zu bestimmen. Die Gemeinschaftsauswertung ermöglicht mit einfachem Index die untersuchten Ökosysteme zum Beispiel für die Bedürfnisse des Naturschützer zu bewerten. Die Methode kann auch für andere Gruppen der Wirbellosen angewendet werden.

SCHLUSSFOLGERUNG

Es ist ein Index der Raubkäfergemeinschaften eingeworfen, dessen Berechnung auf der Aufteilung der Raubkäferfauna in die Gruppen nach der Beziehung zur Standortursprünglichkeit basiert.

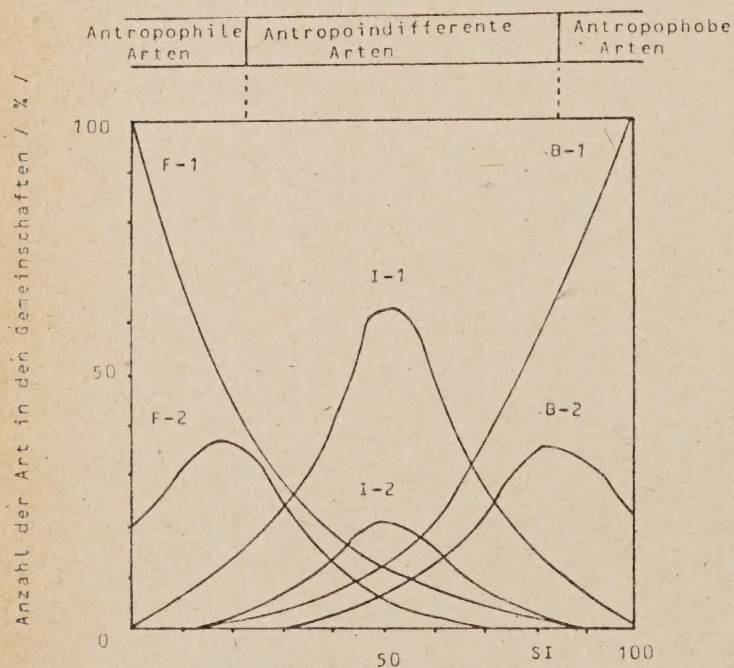


Abb. 2. Die Artenaufteilung abhängig von der Beziehung zwischen dem Indexwert der Raubkäfergemeinschaften (SI) und der Frequenz der Artenexemplare in der Gemeinschaft: anthropophile Arten mit hoher ($F-1$) und niedriger ($F-2$) Frequenz in der Gemeinschaft, anthropoindifferente Arten mit hoher ($I-1$) und niedriger ($I-2$) Frequenz in der Gemeinschaft, anthropophobe Arten mit hoher ($B-1$) und niedriger ($B-2$) Frequenz in der Gemeinschaft.

Auf Grund der Beziehung zwischen dem Indexwert und der Frequenz einzelner Arten wurden 70 näher untersuchte Arten in drei Gruppen: anthropophile, anthropoindifferente und anthropophobe Arten aufgeteilt. Jede dieser Gruppen wurde weiter in die zwei Untergruppen nach der hohen oder niedrigen Frequenz aufgeteilt. Es ist möglich diese Methode auch für andere Gruppen der Wirbellosen anzuwenden.

The use of staphylinid communities (Coleoptera, Staphylinidae) for the bioindication of the environment quality

The index of staphylinid communities for the evaluation of the degree of human influence on ecosystems is proposed. The index is calculated on the base of dividing beetles into ecological groups according to their relation to the naturalness of biotops. All beetles are divided into three groups (antropophilous, antropoindifferent and antropophobous species) on the base of relation between the value of the index calculated for 155 communities, and of the frequency of 70 species in studied communities. Each of these groups can be divided into two subgroups according to the frequency of species. This method is also convenient for other groups of soil invertebrates.

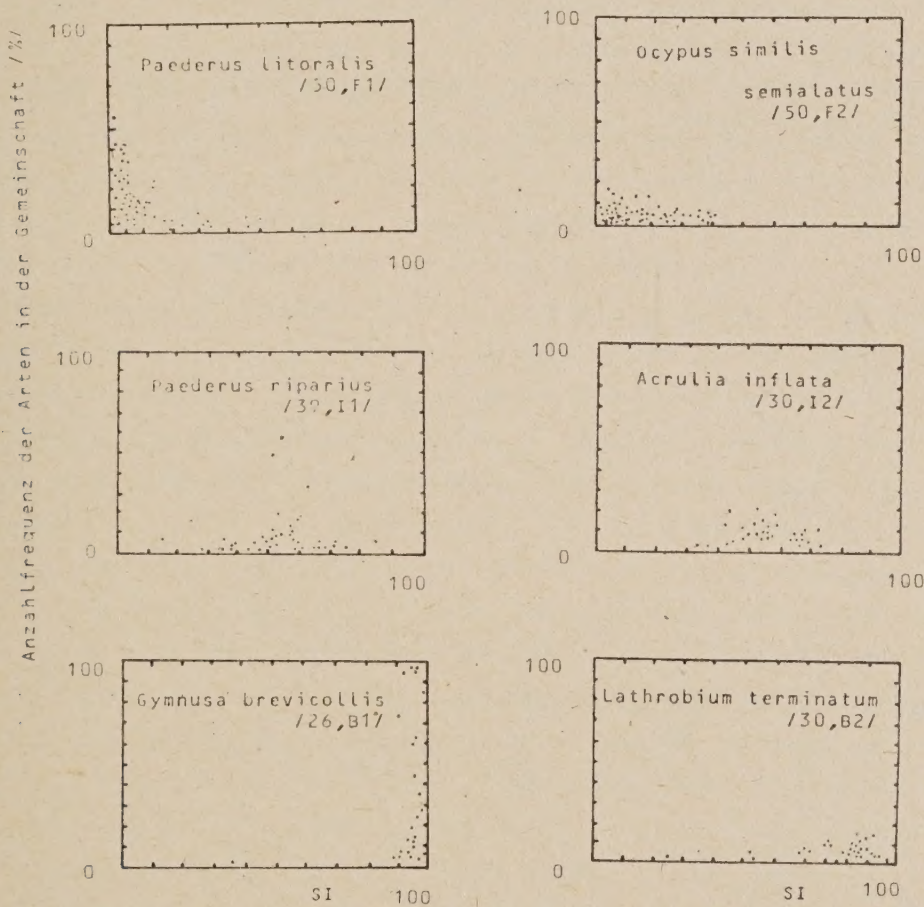


Abb. 3. Die Beispiele der Beziehungsauswertung zwischen SI und der Anzahlfrequenz der Art in der Gemeinschaft bei den anthropophilen, anthropoindifferenten und anthropophoben Raubkäfern (in Klammern Anzahl der ausgewerteten Biotopen und die Inreihung in die Bezeichnungsgruppe wie im Abb. 2).

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Laufkäfer und Indikation von Sukzessionsrichtungen in technogenen Ökosystemen in Westsibirien

W. G. MORDKOWITSCH

Die Gewinnung von Bodenschätzen und hiermit auch die Flächengrößen von technogenen Ökosystemen in Sibirien sind im schnellen Wachstum begriffen. Diese Systeme, deren Gesamtfläche bereits vielen Tausend km² erreicht, sind in der umgebenden Landschaft weit und breit zerstreut.

Seit langem sah man das einzige Ziel der Rekultivierung solcher Ökosysteme nur darin, den beschädigten Grund und Boden für die Land- und Forstwirtschaft zurückzugewinnen. Aber in diesen Ökosystemen bilden sich auch Tauschbestände an Organismen für den Austausch mit den umgebenden Natur- und Landbaulandschaften. Viele Arten von Wirbellosen, welche in natürlichen Ökosystemen nicht auffallen, erreichen in technogenen Landschaften eine grosse Vielzahl. Von hier aus können sie in die benachbarten Landbauflächen migrieren und dort unvorhergesehene Folgen hervorrufen. Deshalb sind die Kenntnisse über die Gesetzmässigkeiten der Introduktion und der gegenseitigen Ersetzung verschiedener Arten von Wirbellosen in technogenen Ökosystemen nicht nur für die Sukzessionstheorie, sondern auch für biologische Indikation von Landschaften von Bedeutung. Eine rechtzeitige Voraussage über die Hauptrichtungen der Sukzession gibt die Möglichkeit, deren für den Menschen ungünstige Folgen vorzubeugen.

Die von uns untersuchten technogenen Ökosysteme gehören zu gleichartigen Reliefbildungen und formen sich auf solchen Gesteinen, welche ähnliche mechanische und chemische Eigenschaften aufweisen. Die Hauptfaktoren, welche zur unterschiedlichen Entwicklung führen können, sind das Alter und die Art der biologischen Rekultivierung solcher Ökosysteme.

Die Laufkäfer (Coleoptera, Carabidae) stellen ein geeignetes Instrument für die Indikation der Sukzession dar, weil sie solche Artgruppen umfassen, welche an bestimmte ökologische Regimen (Steppen-, Wald-, Wiesen- u. a. Ökosysteme) gebunden sind. Ökologische Artgruppen fallen durch deren Verteilung je nach Biotopen im System von topographischen und geographischen Gradienten der Sibirisch-Kasachstanischen Region auf. Die Artenzahl von Laufkäfern in technogenen Ökosystemen West-Sibiriens ist genau so gross, wie in den Naturlandschaften.

Die Laufkäfer treten bei der Besiedlung von technogen entstandenen Halden durch Tiere als Wegbereiter auf. Sie tauschen dort schon ein Tage nach Einschüttung auf, noch früher, als höhere Pflanzen. Deren Vielzahl erreicht dabei etwa 100 Exemplare auf jede 50 Bodenfallen pro Tag. Das sind Vertreter von kleinwüchsigen Arten (Bembidion femoratum, B. quadrimaculatum, B. properans, Microlestes minutulus), welche auch in den Ackerboden- und Weidenökosystemen vorherrschen. Diese Arten vertragen die starken Temperatur- und Feuchtigkeitsschwankungen und auch grosse Salzhaltigkeit gut. In den Ritzen und Rissen, wo sie sich meistens aufenthalten, leben sie davon, dass sie Collembola und vielleicht auch Oribatei fressen, welche in den vom Wind herangebrachten Pflanzenresten hausen.

In den ersten drei Jahren vergrössern sich allmählich die Vielzahl und die Verschiedenartigkeit von Laufkäfern in den sich spontan mit Gras bewachsenden technogenen Ökosystemen. Weiter, die Richtung und der Charakter der Sukzession hängen nicht nur vom Alter der Ökosysteme, sondern auch von der Art deren biologischer Rekultivierung und auch von der Wahl der Baumarten ab.

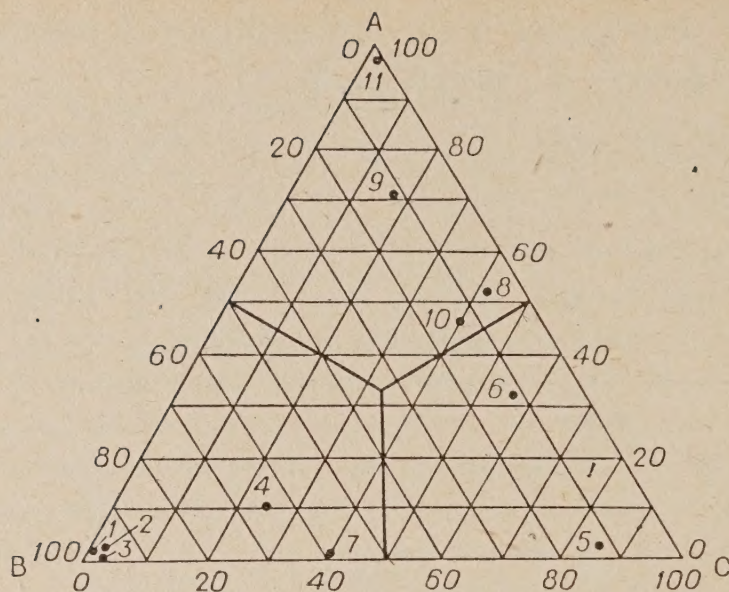


Abb. 1. Richtungsdiagnostik der Ökologischen Sukzession.

A - Wald-, B - Steppen-, C - Wiesenartige Sukzession.

Rekultivierte Ökosystemen: 1 - Ohne Pflanzendecke, 1,5 Jahre alt; 2 - Halophytenwachstum, 1,5 J. a.; 3 - Dicke Unkräuter, 2 J. a.; 4 - Hippophaë rhamnoides-Gesträuch, 7 J. a.; 5 - H. rhamnoides und Kiefern-Gesträuch mit spärlicher Grasdecke, 7 J. A.; 8 - Gras- und Hülsenpflanzenwaldwiese im Birken-, Weiden-, Kiefernholz, 25 J. a.; 10 - Dicker Birkenwald mit spärlicher Grasdecke, 18 J. a.

Natürlichen Ökosysteme: 7 - Gras- und Kräutwiesensteppe, 9 - Kiefern- und Birkenwald, 11 - Fichtentaiga.

Auf der Abb. 1 wird die Stellung von Laufkäfergesellschaft im System dargestellt, welche die Hauptrichtungen der Sukzession (Wiesen-, Steppen-, oder Waldausbildung) bestimmt, dabei werden die Prozentsätze jeweiliger Ökologischer Gruppen zugrunde gelegt. Je mehr die Punkte, welche die Projektionen jeweiliger Gesellschaften darstellen, sich den Winkeln des Dreieckes nähern, desto vollständiger wird die Richtung charakterisiert, in welcher sich die jeweilige Gesellschaft entwickelt.

Die Sukzession nach dem Steppentyp ist für die wegbereitenden Grasökosysteme (1 bis 3 Jahre alt) charakteristisch. Nach drei Jahren, also auf dem Stadium des unkrautbewachsenen Brachlandes, weisen diese Ökosysteme viel mehr der zur Steppenart gehörenden Laufkäfer auf, als die natürlichen Übergangsökosysteme der umgebenden Waldsteppenlandschaft, die Wiesensteppen. Nach dem Typ der Steppenlandschaft entwickeln sich auch die Ökosysteme in den nicht dichten Hippophaë rhamnoides - Gesträuch. Auch zusammen mit Kiefern schließen die Weiden-Sandhorn das Auftreten von Laufkäfern aus. Also, auch in den Waldpflanzungen geht die Sukzession nicht nach den Wald, sondern nach dem Wiesentyp vor sich.

Die rekultivierte Wälder weisen auch in der Waldlandschaft, bei gutem Baumbestand nach 18 bis 25 Jahren eine solche Laufkäfergesellschaft auf, in welcher die Waldarten nicht mehr als 50 % Gesamtbestand ausmachen. Auch die Wiesenarten sind mit gleichem Prozentsatz vertreten.

Also, auch die Rekultivierung, welche mit der natürlichen Entwicklung der Sukzession in der gegebenen Landschaftzone übereinstimmt, sichert die Wiederherstellung der ursprünglichen Ökosysteme nicht in vollem Masse. Die sich neu bildenden Tiergesellschaften gehören immer zu einem xeroformener Typ.

Indication of environmental heteromorphy and habitat fragmentation by invertebrate communities in grasslands

L. GALLÉ, G. GYÖRFFY, E. HORNUNG, L. KÖRMÖCZI

INTRODUCTION

There have been intensive changes in the geographical pattern of Hungarian landscapes in the last decades. Natural and quasi-natural areas are disappearing and becoming fragmented as a consequence of extensive agriculture and industrial activity. The size of original grasslands (pastures, "pusztas", forest-steppes and even farm-yards) and forest patches is diminishing, and the South Hungarian landscapes yet being mosaic-like are transforming into monotonous, human-made agricultural and industrial areas.

This paper is a community-focused approach of possibilities to study the indication of the degradation processes by different ecological communities and their resistance.

The main questions we would like to answer are as follows:

1. How do different ecological communities indicate spatial heteromorphy in a mosaic-like landscape?
2. Are they persistent in fragmented habitats of different size?
3. What is their reaction to man-induced stresses?
4. What are the main effects influencing ecological communities in habitat-islands?
5. What groups to be used in landscape planning?
6. Can quasi-natural ecological communities be maintained in the South Hungarian Plain?

STUDY AREAS AND METHODS

For the indication of habitat heteromorphy a sandy grassland was studied in the Kiskunság National Park. Samples were taken during nine years continuously from March to November in each year. To distinguish "coarse-grained" and "fine-grained" responses (LEVINS, 1962, MacARTHUR, LEVINS, 1964) of the communities our null hypothesis is that populations belonging to the studied communities have the same probability in their occurrences in any patch of the habitat in question (postulate of uniformity, DIGGLE, 1979). The departure from this random null model was tested by comparing similarity values among sampling sites on the basis of different communities and randomly constructed fictive assemblages. Obviously the similarity values of a certain community that are markedly lower than that of random models, indicate coarse grained response. Plants and the communities of Heteroptera, Cicadinea, Isopoda, Collembola, Diplopoda, Formicoidea, Acridoidea, Aranei, Sphecidae and Carabidae were involved in this investigation. The stability of the patches as well as their reaction to human perturbances were examined by the analysis of the persistence of communities in different patches exposed either only to natural stress (i. e. drought) or experimentally induced perturbations simulating man's influence, i. e. spraying, fertilization, insecticides, short-term isolation, grazing and removing the upper surface of soil.

The effect of long-term isolation was investigated in cemetery hills ("kurgans") having been covered by quasi-natural grasslands for hundreds of years and surrounded by agricultural fields, BOHÁČ J., RŮŽIČKA V. (eds.), 1989: Proc. Vth Int. Conf. Bioindicators Deteriorisationis Regionis. Institute of Landscape Ecology CAS, České Budějovice, pp. 167-170.

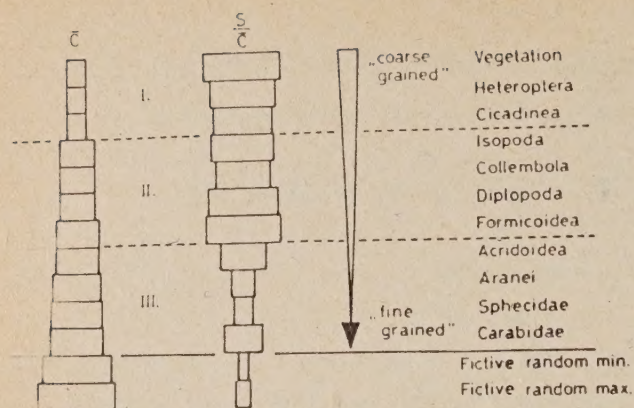


Fig. 1. Average similarity values (C) and their coefficients of variation (S/C) among patches of a mosaic-like grassland on the basis of different communities and random models.

as a rule. Six of such habitat islands were sampled for invertebrates in 1985 and at least thirty samples were taken in each.

OUTLINE OF THE RESULTS

As it can be seen in Fig. 1, the most coarse grained response is performed by plant communities and sucking insects (Cicadinea, Heteroptera), associated closely with food plants. Isopods, springtails, diplopods and ants form a transitional group and grasshoppers, spiders, digging wasps and ground beetles have the highest similarity values reflecting their fine grained response considering both similarity values among sites and their coefficients of variation (Fig. 1, for details see GALLÉ et al., 1987).

On the basis of persistence analysis it seems that the deeper, moist patches of the studied sandy soil grassland are the most instable regarding the majority of studied animal groups and plants. Their fauna and vegetation show directional changes as a consequence of the dry period in early and mid-80s.

Considering the perturbation-induced changes in the diversity as well as in the composition of the different communities, the most intensive effects are resulted by fertilization and long-lasting grazing. Recovery of animal assemblages is shorter after removing soil surface. Water-spraying causes unimportant effects on the communities in higher, drier sand dunes and it is advantageous for the persistence of communities in the deeper wind grooves, otherwise threatened by drying. From among the groups we studied, macrodecomposers are the most sensitive for all perturbations, ants are effected first of all by perturbations in the deeper wind grooves, as it could be established from multivariate analysis. The alternations of Cicadinea reflect the perturbation induced changes of plant communities.

In the habitat islands we found no significant relation between habitat size and the number of species in most cases. This fact contradicts the predictions of the classical island biogeography models (MacARTHUR, WILSON, 1967). Only one regression slope falls in the range expected from the classical theory (Isopods, $b=0.22$), but the correlation is not significant either in this case. Interestingly the only significant correlation is negative: $r=0.74$, $p<0.1$ (Cicadinea). We could not detect checkerboard distribution (DIAMOND, 1975) in any group, the distributional data do not differ from null models with fix marginal sums (for the suitability of null-hypotheses see CONNOR, SIMBERLOFF, 1979; QUINN, DUNHAM, 1983; STRONG et al., 1984).

Tab. 1. The main differences between real and ecological islands.

	Real islands	Habitat islands
Colonization source	mainland	other islands
Colonization rate depends on	distance from mainland	distance from other islands
Extinction depends on	size	size and the surrounding biota
Surrounding areas	see	agriculture lands
Relation between islands and surrounding communities	weak	strong (invasion is expected)

The unexpected properties of these habitat-island communities can be explained by the differences between real and ecological islands (Tab. 1).

Summarizing the results, the reference indicator communities of habitat heterogeneity and fragmentation, that are applicable in small-scale landscape (e. g. reserve) planning are as follows. The critical size of a homogeneous grassland can be established on the basis of fine-grained behaviour groups demanding relatively large areas as grasshoppers among invertebrates and most of vertebrates. In a heterogeneous habitat the minimal patch size can be decided on the basis of ants requiring larger patch size to establish persistent communities. The maximal patch size is limited by communities that maintain their high diversity by migration among patches such as leafhoppers. The maximal distance of patches must be determined by the communities consisting of populations of low dispersal ability (e. g. decomposers).

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Use of bird communities for ecological evaluation of small wood patches in agricultural landscape

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INTRODUCTION

Woods of medium area and even small wood fragments function as important centres of biological diversity of environment in agricultural landscape. Great number of species, often very dense, is generally concentrated to small isolated woods. For managing and founding, of small wood patches it is useful to know the influences of factors affecting the number of species and abundances of animal communities.

METHODS

The aim of investigation was to examine species composition and density of breeding bird communities in relation to the geometry and habitat structure of small wood patches. 36 small (0.2 - 12 ha) woodlots in Třeboň Biosphere Reserve (South Bohemia), which were separated from other forests on all sides by at least 300 m (300 - 800 m) distance, included deciduous, mixed and coniferous forest stands. Birds were surveyed with standard mapping method (ENEMER, 1959) and sampling procedures of vegetation were based on the methods of CYR (1977).

RESULTS

From the analyses of Třeboň Biosphere Reserve woodlots resulted that bird communities indicate the optimal and critical values of these factors: the area and fragmentation of woods, composition of tree species and ages in wood, horizontal and vertical structure, and the total diversity of stands.

Number of breeding bird species increases rapidly up to the areas of 1 - 2 ha while further dependence approximates linear growth (Fig. 1). Greater diversity of bird communities is found rather in grown up deciduous and mixed than in predominantly coniferous stands, especially if a wood is divided in several vegetation levels (factor FHB, Fig. 2). Abundance and density of birds closely relate to the structure and age of stands (Fig. 3 and 4). From vegetation profiles it is evident that greater abundance of birds is achieved by grown up (mature) and sufficiently vertically itemized stands of these woods.

DISCUSSION

Power and exponential species area equations ($S = CA^z$, where S = number of species, A = area, C and z fitted constants) generally describe the connection between bird species richness and area of small forest (GALLI et al., 1976; HOWE, 1984; CIESLAK, 1985; HELLE, 1986; BLAKE, KARR, 1987). Association between area and number of bird species does not necessarily indicate a direct relationship.

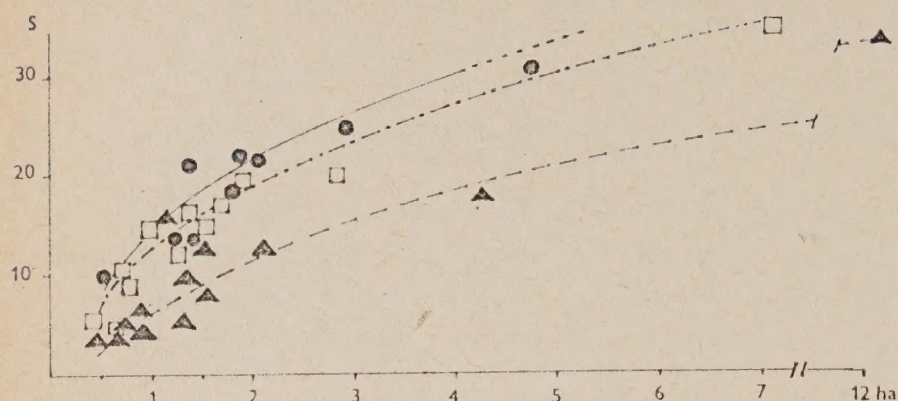


Fig. 1. Relations between number of bird species (S) and area (ha) of deciduous, mixed and coniferous wood patches in Třeboň region.

□ --- deciduous woods,
● --- mixed woods,
▲ --- coniferous woods.

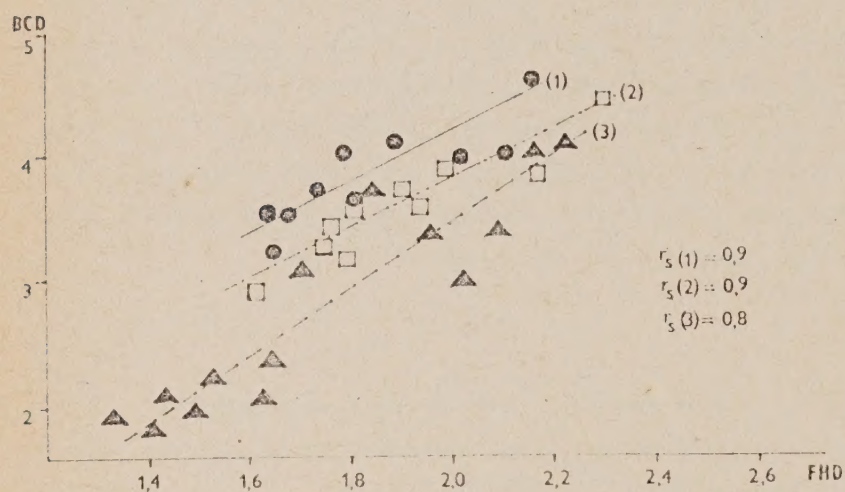


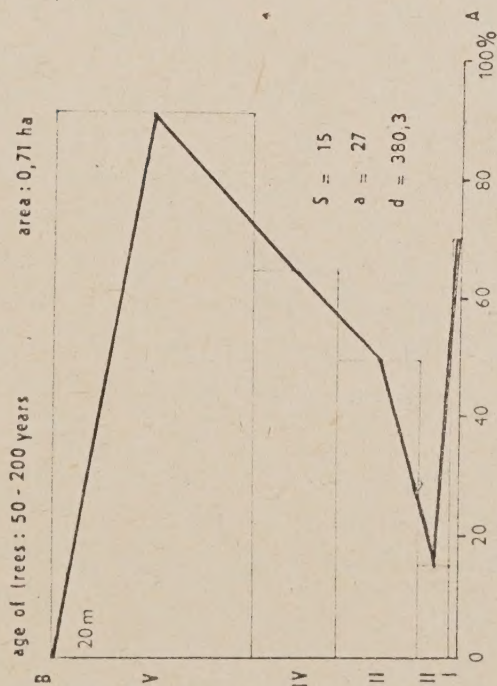
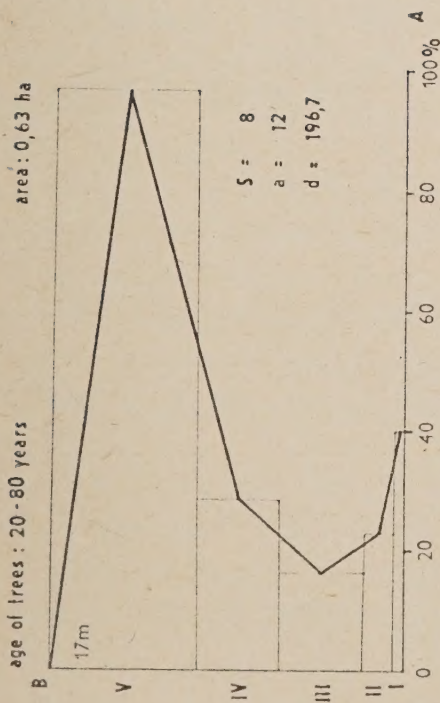
Fig. 2. Diversity of bird communities (BCD) and foliage height diversity (FHD) of vegetation in deciduous, mixed and coniferous wood patches in Třeboň region. Leg. as in Fig. 1.

$r_s(1) = 0.9$
 $r_s(2) = 0.9$
 $r_s(3) = 0.8$

Abundance of one-third to one-half of species examined correlated with woodlot area, but a greater proportion (66 - 72 %) was influenced more strongly by habitat variables (BLAKE, KARR, 1987). This may be due to statistical intercorrelations between patch area and other habitat variables, some of which may exert a more direct influence on bird numbers than does the area per se. Thus, within the range of patch area (generally 5 - 1 000 ha) and isolation (generally 0.1 - 1 km) LYNCH et WHIGHAM (1984) considered vegetation characteristics, rather than forest geometry appear to play dominant role in determining community composition and the local abundance of individual bird species. Mature wood patches supported roughly twice as many bird species per unit area as younger forest phases (HELLE, 1984). The number of age classes of wood in patches up to 1 ha affects negatively the number of bird species, but as the wood size increases this factor becomes a positive one (CIESLAK, 1985).

HELLE (1986) concluded that in boreal forests the total coverage and foliage height diversity (FHD) were best predictors of bird density and height of vegetation and FHD of bird species diversity. The same conclusions about the influence of FHD were presented by other authors (ERDELEN, 1978; CYR, CYR, 1979; BILCKE, 1982). Number of bird species in small woods was significantly associated also with canopy tree species diversity (Wisconsin - HOWE, 1984; Finland - HELLE, 1986), with coverage of shrublayer (CYR, CYR, 1979; CIESLAK, 1985), and understory cover (HOWE, 1984).

DECIDUOUS WOODS



CONIFEROUS WOODS

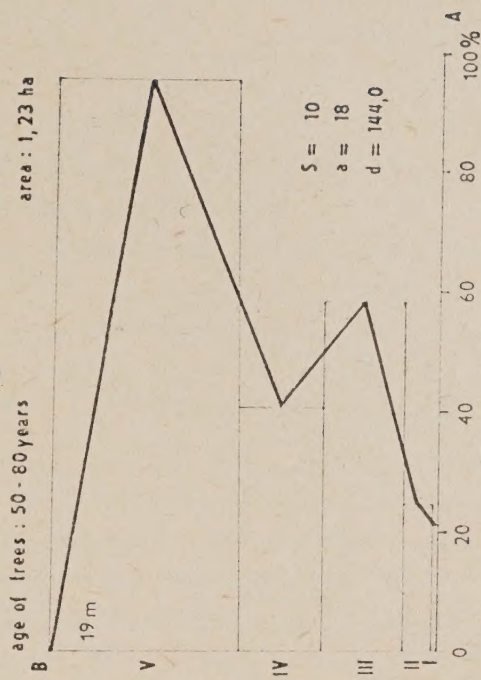
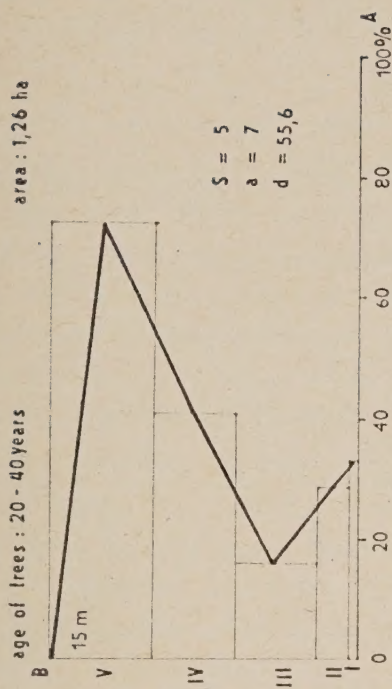


Fig. 3. Relation between vegetation profile in deciduous woods and bird community. S - number of species, a - abundance, d - density, A - cover of vegetation, B - level of vegetation (I: < 0.5 m, II: 0.6 - 2 m, III: 2.1 - 6 m, IV: 6.1 - 10 m).

Fig. 4. Relation between vegetation profile in coniferous woods and bird community. Leg. as in Fig. 3.

Most authors concluded that the occurrence of many species can be predicted better from the structural and floristic characteristics of woods than from patch size and isolation. However, in the uniform series of woods habitat differences play a minor role and the distribution of most bird species, as well as avian communities, are predicted best from patch size (OPDAM, RIJSDIJK, HUSTINGS, 1985).

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Small mammal communities as bioindicators of man's interference with wetland ecosystems

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In southern Bohemia, wetlands (including shallow stagnant waters, streams, reed beds, bogs, and flooded lowland forests and meadows) are among important components of local landscape. In the rather flat terrain, such wetland communities often form a continuous series. In southern Bohemia this series is of considerable landscape-forming and economic importance, as it covers extensive areas. Endeavours to find optimum utilization of wetland ecosystems for agriculture, water management and nature conservation are long-standing. The same aims were pursued in integrated ecological investigations, carried out at Mokré Louky near Třeboň and co-ordinated by the Botanical Institute of the Czechoslovak Academy of Sciences. Our share in these investigations was, among other things, to study the bioindicative and biodiagnostic value of communities of small terrestrial mammals found in waterlogged meadows which had been subject to various degrees of man's interference, such as draining, mowing, fertilization, and supplementary sowing.

It should be emphasized in this place that small terrestrial mammal communities have not been considered as current bioindicators. Rather, bioindication has utilized variation in selected populational, physiological or biochemical characteristics of selected small mammal species.

Our investigations were conducted in the locality Mokré Louky, as mentioned above. This is an area of 450 hectares, lying at the eastern to north-eastern edge of the town of Třeboň. It is covered by cultivated peat bogs, marshes and willow stands growing on a layer of humolit several metres deep. The hydrology of the locality is affected, on the one hand, by seasonal flooding during periods of spring snow melt and after summer rainstorms and, on the other, by water levels in the Rožmberk fishpond, controlled for the purpose of fishery management.

The following three different habitat types were involved in our investigations:

Magnocaricetum (Mg). This is an irregularly flooded habitat comprising a mosaic of areas dominated by Calamagrostis canescens, and Carex gracilis, and areas with Glyceria maxima. Their vegetation was up to 1.5 metres tall and the sedges produced distinct tussocks. The spaces between the tussocks lacked continuous vegetation and the ground water level was above or close below the soil surface. The locality was never drained or mown.

Molinietum (Mo). This is an irregularly mown meadow, having once received supplementary sowing, with predominant Deschampsia caespitosa, Alopecurus pratensis, Sanguisorba officinalis, Poa pratensis, and Carex rostrata. Quite exceptionally the habitat has been affected by flooding.

Mown meadow (Mm). This is a regularly mown, resown and fertilized meadow with a rather perfect drainage system. Not a single flood occurred there during our study period. The habitat was dominated by Alopecurus pratensis; there were numerous Poa pratensis, Taraxacum officinale, Ranunculus repens, and Deschampsia caespitosa.

Between October 1979 and October 1983 we captured, in the above habitats, a total of 1191 small mammals belonging to ten species. They were captured in snap-traps of the common type, laid in standard trapping quadrats of 11 rows, each with 11 trapping points spaced 10 metres apart. The traps were exposed for six consecutive nights on each trapping effort. Two such trapping quadrats were plotted in each of the three habitat types mentioned above; one of them was used for spring trapping (in late May), the other for autumn trapping (in late September).

The population densities of the individual species were determined from the catches obtained in the trapping quadrats, using a four-step method: elimination of the edge effect; calculation of the estimated catch size (N); determination of the effectively trapped area; and conversion of N to hectare density. Productivity was calculated using the standard procedure.

Analysis of the trapping data reveals several trends of their variation from Mg through Mo to Mm. Considering the catches of small mammals in successive years, it was in Mg that their density and productivity showed very indistinct variation in spite of the floods, which are known to be associated with emigration of small mammal populations. To a relatively lesser extent, a similar phenomenon was observed in Mo. Sharply contrasting was the situation in Mm where the density and in fact all energetic characteristics showed dramatic year-to-year changes.

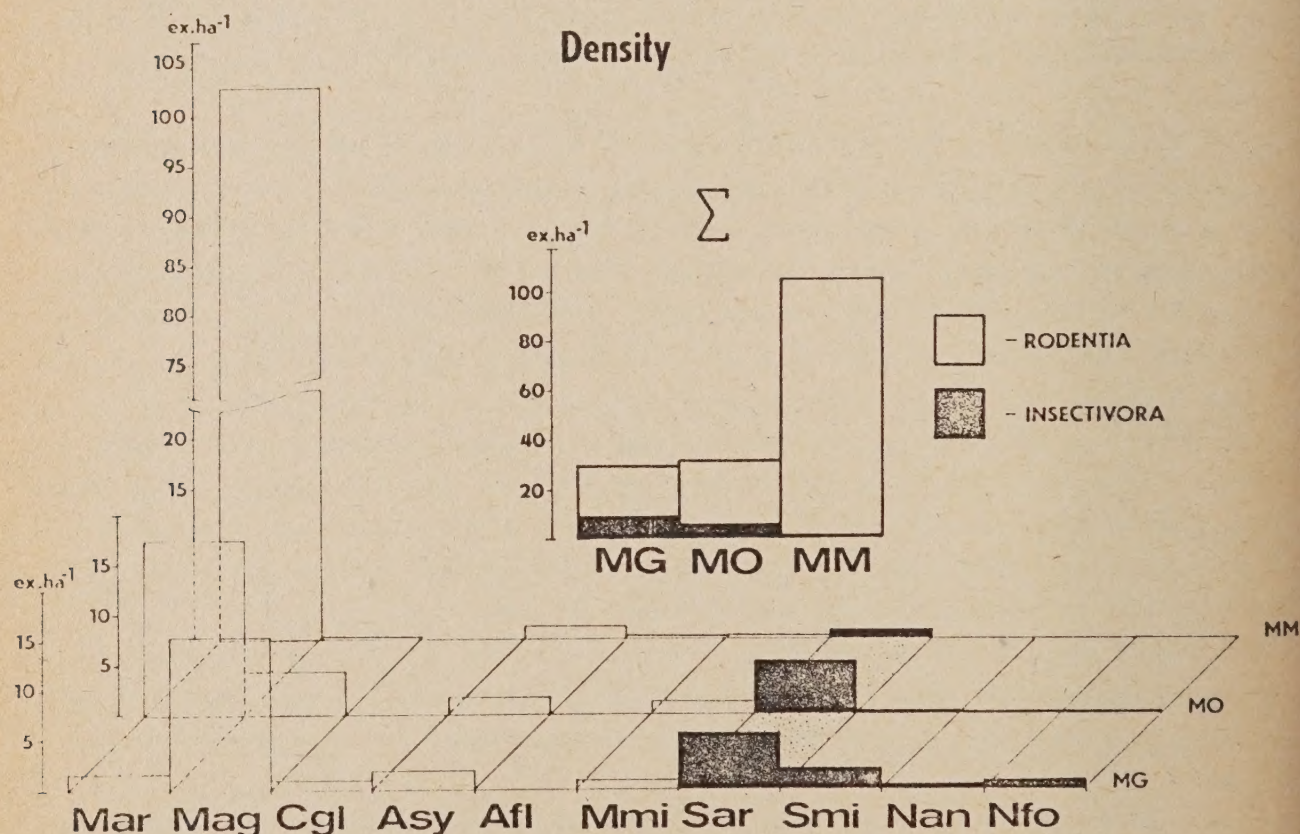


Fig. 1. Density of small mammals in habitats investigated. MG - Magnocaricetum, MO - Molinietum, MM - mown meadow. Mar - *Microtus arvalis*, Mag - *Microtus agrestis*, Cgl - *Clethrionomys glareolus*, Asy - *Apodemus sylvaticus*, Afl - *Apodemus flavicollis*, Mmi - *Micromys minutus*, Sar - *Sorex araneus*, Smi - *Sorex minutus*, Nan - *Neomys anomalus*, Nfo - *Neomys fodiens*.

They were mainly due to the population of *Microtus arvalis*, the major component of the small mammal community in Mm. The tall and often waterlogged vegetation of *Carex*, *Glyceria* and *Calamagrostis*, covering the habitats in Mg and Mo, does not comply with the voles, which prefer drier habitats with lower grass cover. We could demonstrate the effect of the height of vegetation on the occurrence of *Microtus arvalis* in Mo. As long as the habitat was not mown, common voles occurred there very sporadically. Already the hay harvest in the summer of 1981 caused an increase in the vole population density, as indicated by the following values:

May 1981, 0.6 voles per hectare; October 1981, 70.8 voles per hectare. Populations of *Microtus agrestis*, preferring habitats with tall and moist herbaceous vegetation, are not subject to such marked cyclic oscillation (Fig. 1).

We also found considerable differences in energetic characteristics and, consequently, in the consumption of plant and animal matter by the whole small mammal community between Mg and Mo on the one hand, and Mm on the other. The mean annual consumption of plant matter (dry weight) was $32 \text{ kg} \cdot \text{ha}^{-1}$ in Mg, about $27 \text{ kg} \cdot \text{ha}^{-1}$ in Mo, and about $123 \text{ kg} \cdot \text{ha}^{-1}$ in Mm.

We found a quite contrary trend in the consumption of animal matter. While the annual consumption was $6.5 \text{ kg} \cdot \text{ha}^{-1}$ in Mg and about $5 \text{ kg} \cdot \text{ha}^{-1}$ in Mo, it corresponded to about $2 \text{ kg} \cdot \text{ha}^{-1}$ in Mm (Fig. 2).

□ - vegetable
▨ - animal

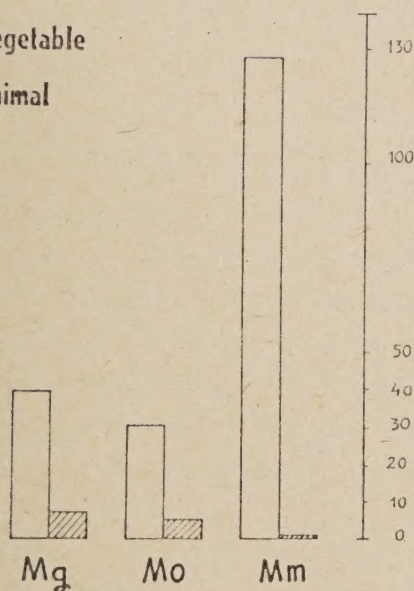


Fig. 2. Consumption of food (kg dry weight . ha⁻¹ . year⁻¹).

Dominance

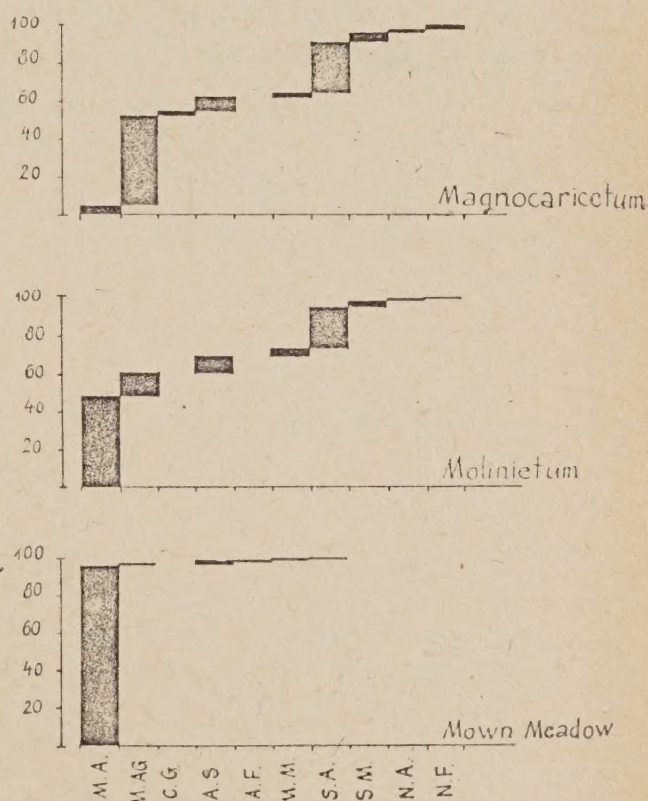


Fig. 3. Dominance of individual species in localities investigated. Explanation see Fig. 1.

The above correlations may be elucidated by analysis of the dominance values of the various small mammal species. In Mg the relative representation of largely herbivorous species (Microtus arvalis, Microtus agrestis, Clethrionomys glareolus, Apodemus sylvaticus, Micromys minutus) attained 65 %. Second and higher order consumers made up roughly 35 % of the community. In Mo, omnivores made up about 27 %, whereas in Mm they hardly attained 1 % (Fig. 3).

Management of meadows, including their drainage, mowing, fertilization and supplementary sowing, results in rapidly decreased species richness of the small mammal community. We found nine species in Mg, eight in Mo and only six in Mm. Of these six species, three occurred singly and their occurrence may be considered as accidental in regard of the character of the habitat.

The number of species and their relative representation in the samples were reflected even in the value of Shannon's species diversity (H'). From 2.20 in Mg, this value decreased to 2.11 in Mo and dropped abruptly to a mere 0.31 in Mm. Sheldon's equitability index (E) was 0.69 in Mg, 0.70 in Mo and again dropped down to 0.12 in Mm.

The data obtained confirm that communities of small terrestrial mammals may serve as reliable bioindicators of changes brought about in the regimen of wetlands by draining, fertilization, or supplementary sowing. Such man-made alterations result in a gradual decrease in species diversity; differences between productional minimums and maximums increase; this fact is reflected even in the consumption of plant matter by the small mammal community. At the same time, the percentage of second and higher order consumers is considerably decreased, which fact is connected with decreased consumption of animal matter.

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The use of the house martin, Delichon urbica, as a bioindicator of air pollution

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INTRODUCTION

Air pollution is a continuing worldwide problem. National and international biomonitoring programs have been established to evaluate the effects and status of ecological systems effected by air pollution (NEWMAN, SCHREIBER, 1984). Air pollution has been shown to effect a variety of ecosystem components, including birds. The reported effects on birds have included bioaccumulation (KERN et al., 1981; JENKINS, 1980), respiratory lesions (McARN et al., 1974), mortality (HARRIS, 1971; YONT, SAYERS, 1927; BICKNELL, 1983) and population reductions (FERANICOVÁ-MASAROVÁ, KALIVODOVÁ, 1965). Concern has recently grown regarding the effects of acid rain on bird populations (ERIKSSON, 1984).

Birds have a long history of being used as bio-indicators for environmental change (TURCEK, 1972). Canaries were used as bio-indicators of air pollution by early miners. Studies in Great Britain and Czechoslovakia have shown the house martin, Delichon urbica, is sensitive to air pollution. The house martin is an insectivorous species which feeds primarily on aphids and dipterans (BRYANT, 1973). As a migratory species, it breeds throughout Europe and winters in Africa (HEINZEL et al., 1977). In Czechoslovakia and England the house martin arrives and begins nesting during April and May (HUDEC, VACKAR, 1977; SHARROCK, 1977) and departs in September and early October. Because of its response to air pollution and life history characteristics, the house martin makes an ideal air pollution bio-indicator. This paper describes the use of the house martin as a bio-indicator of air pollution.

CHARACTERISTICS OF AIR POLLUTION BIO-INDICATORS

Bio-indicators have been defined in a number of ways but generally are considered as organisms whose presence or absence or other characteristic response indicates certain environmental conditions. The use of biological indicators as measures of air pollution is extremely valuable for several reasons: 1. they integrate all environmental effects and reflect the total environment; 2. they correlate the physical and chemical measures of air quality with biological effects; 3. they reveal trends or changes in the environment; 4. they allow for a more realistic assessment of air quality standards. Useful biological indicators have some combination of the following characteristics:

- common or abundant in polluted situations
- widespread geographical distribution to allow for long range surveillance and universal use
- indicative of ecological response to air pollutants, i.e., a measure of sum of environmental variables plus pollutants
- observable or measurable

- allow for precision and accuracy, i.e., reproducible and consistent results
- sensitive to pollution with well defined and uniform response
- site specific response
- low cost in terms of measurement

RESPONSE OF HOUSE MARTIN TO AIR POLLUTION

The house martin has been observed to be sensitive to air pollution. CRAMP et GOODERS (1967) observed an increase in nesting of the house martin in the inner city of London in the 1960's compared to the 1950's. This increase in nesting appeared to be correlated with a decrease in "smoke" pollution. The largest concentration of house martins were found in areas with particulate concentrations less than $30 \mu\text{g}/\text{m}^3$. No nests were found in areas with particulate concentrations greater than $50 \mu\text{g}/\text{m}^3$. BOULDIN (1968) found house martin populations lower in industrialized areas of Manchester, England than in less industrialized areas. FERIANCOVÁ et KALIVODOVÁ (1965) and FERIANCOVÁ-MASAROVÁ et al. (1985) have found an inverse correlation between bird diversity (including the house martin species) and fluoride emissions.

Detailed studies in Czechoslovakia of the house martin have shown that the nesting density, colony size, and occupancy have declined with increasing exposure to air emissions (NEWMAN et al., 1985). Observations from 1976 to 1983 in over 130 localities revealed that the nesting density was significantly ($P < 0.002$) reduced by 45 percent in polluted areas and the colony size by 28 percent and occupancy by 44 percent (Tab. 1).

Over 80 percent of the observed variability in nesting density and in colony size and occupancy in background areas were explained by certain factors. Ecological factors the type of building, distance from water body, soil type, human use, and regional relationships significantly influence nesting. Fewer ecological quality factors significantly influenced the nesting of the house martin in polluted areas compared to background areas. Building type and distance from water had the most influence in polluted localities. Air quality related factors such as the type of emission source, wind direction and distance for emission source were found to significantly influence nesting density, colony size and occupancy in contaminated localities. When certain ecological factors were controlled a greater percentage of the variability observed in the nesting density and colony size and occupancy could be explained.

Tab. 1. Comparison of nesting density, colony size and occupancy in background and contaminated localities for all years (1976, 1978 and 1983).

Background values significant different from contaminated values (t Test, $P < 0.002$).

Number of localities	Background 57	Contaminated 134
Nesting Density	0.62 ± 0.42	0.34 ± 0.53
Colony Size	2.83 ± 1.59	2.04 ± 1.57
Building Occupancy	22.61 ± 9.23	12.73 ± 12.61

Tab. 2. Comparison of nesting density, colony size and occupancy ($\pm$ S. D.) contaminated localities compared to selected air quality factors for all years (1976, 1978, and 1983).

- Significantly different from upwind ($P < 0.09$, t Test)
- Significantly different from downwind ($P < 0.05$, t Test)

Number of localities	All Emission Sources		pulp Mills
	Upwind 24	Downwind 110	Downwind 13
Nesting Density	0.50 $\pm$ 0.45	0.31 $\pm$ 0.54•	1.23 $\pm$ 1.48••
Colony Size	2.53 $\pm$ 1.57	1.93 $\pm$ 1.57•	3.12 $\pm$ 1.92••
Occupancy	17.86 $\pm$ 10.44	11.6 $\pm$ 12.80••	31.88 $\pm$ 23.45••

Except for localities with pulp mills the nesting density, colony size and occupancy is negatively correlated with emission source such as cement plants etc. Downwind nesting localities have lower nesting than upwind localities (Tab. 2). Nesting is inversely related to distance from emission source.

CHARACTERISTICS OF THE HOUSE MARTIN AS A BIO-INDICATOR

The ecological characteristics of the house martin make it an ideal bio-indicator. The house martin as a colonial nesting species is readily observable and easily measurable. Nests are mud or clay structures with a single opening attached to the outside of buildings. The preferred nesting locations are on walls under eaves of roofs, window overhangs, perpendicular cornices, and other projections from buildings (LIND, 1964). The nest is constructed of hundreds of small clumps of wet mud or clay obtained from within a short distance of the nest site. The mud or clay formed nests attached to the outside of buildings are easily counted from ground. Observers need only to record the number of active and inactive nests.

Masonry or stone are the preferred surfaces for constructing nests: inhabited rather than uninhabited buildings are preferred for location of the nests (LIND, 1960). Because of this association with human habitation the house martin can be used as a monitor for the human environment. Its association with the built environment results in the potential for the house martin to be exposed to a variety of air quality conditions. In Czechoslovakia the house martin has been found to nest in a number of industrial situations, including around power plants, surface mines, cement plants, chemical factories, and pulp mills.

The house martin has a very wide geographical breeding range. It is found throughout Europe from sea level to over 950 meters above sea level (KROYMANN, MATTES, 1972) and at latitudes as far north as Finland (LIND, 1960). As a result of this distribution, it is suitable for long range surveillance and wide use.

Our previous study (NEWMAN et al., 1985) has shown that the nesting response of the house martin is a measure of the sum of a number of ecological and air quality factors. Its response is an integration of these factors. In contaminated areas, air quality factors were found to be the most significant factors influencing nesting.

Studies in Czechoslovakia have shown that the responses of the house martin are reproducible and consistent within the same set of environmental conditions. Over an eight year period the nesting characteristics in different localities did not significantly change if the environmental

Tab. 3. Comparison of nesting density, colony size and occupancy ($\pm$ S. D.) over an eight year period 1976 to 1983. 1976, 1978 and 1983 values not significantly different from one another. in parentheses: no. of localities.

	1976	1978	1983
BACKGROUND	(6)	(32)	(19)
Density	0.56 ± 0.26	0.56 ± 0.30	0.75 ± 0.57
Colony Size	3.34 ± 2.20	2.76 ± 1.18	2.86 ± 2.00
Occupancy	19.84 ± 6.15	20.71 ± 8.73	26.68 ± 9.83
CONTAMINATED	(31)	(82)	(21)
Density	0.37 ± 0.66	0.33 ± 0.45	0.36 ± 6.1
Colony Size	1.77 ± 1.13	2.01 ± 1.41	2.33 ± 2.51
Occupancy	13.87 ± 16.79	12.6 ± 11.41	11.52 ± 10.19

conditions did not change (Tab. 3). Where there was a change in air quality there was a subsequent change in nesting patterns. The house martin shows a permanency in nesting over several generations, i. e., subsequent generations return to the same nest site (RHEINWALD, GUTSCHER, 1969). This characteristic assures stability in nesting unless environmental conditions change.

Delichon urbica has been shown to be sensitive to air pollution with well defined and predictable responses, i. e., changes in nesting density, colony size, and nest site occupancy. Because of the permanency of nesting over several generations, the bio-indicator response is a site specific response reflecting the conditions of a given locality. One of the most important characteristics of the house martin as a bio-indicator is that the sampling costs are low, only observer time is required. No sophisticated or expensive equipment is necessary. Observers can be easily trained.

There are some limitations to the use of the house martin to air pollution. The actual mechanism causing the response is not known i. e. direct effects to the birds or effects to its food resources the however, response is diagnostic of air pollution conditions. Information is also needed on the response of the house martin to various ambient air quality levels. It's is adversely effected by "high" air pollution from a variety of emission sources except pulp mills. The reasons for this observations is not known.

Another limitation is that the house martin does not reflect environmental conditions during the fall and winter, since it migrates to Africa during this period of the year. Additional variability could arise if the population is adversely affected in its wintering area. However, if this were to occur there would be similar effects in both background and contaminated localities.

MEASURES OF RESPONSE AND DATA ANALYSIS APPROACHES

Measures of population size have varied for the house martin. Previous workers have recorded the number of birds observed (CRAMP, GOODERS, 1967) or the number of nests (i. e., colonies) found in a village or on a group of buildings (LIND, 1964; BEENEN, 1970). Others have reported nesting density as the number of pairs per building (LENZ et al., 1972). BOULDIN (1968), recognizing that some geographical areas were unsuitable for nesting, estimated the density of house martins by adjusting the area used for calculating nesting density.

Tab. 4. Ecological and air quality factors potentially effecting the nesting of the house martin in Czechoslovakia (adapted from NEWMAN et al., 1985).

• = Important factors

Ecological factors	Air quality factors
<u>Climatic type of region</u>	<u>Type of emission sources influencing site</u>
Warmer and drier	Power plants
Cooler and wetter	Surface coal mine
	Cement plants
	Aluminum plant
	Chemical plant
<u>Elevation</u> •	Pulp mills
	Steel mills
<u>Biogeocoenosis (ecosystem) type</u>	General urban sources
Floodplain	Major highways
Beech oak	Airport industries
Oak beech	Local heating plants
Oak coniferous	Food processing plants
<u>Proximity to water</u> •	
Less than or equal to 1 km	<u>Prevailing wind from emission source</u> •
Greater than 1 km	Upwind
	Downwind
<u>Soil type</u> •	<u>Size of emission source</u>
Mostly clay soil and clays	Stack height greater than 120 m
Mostly clay-loamy soils	Stack height less than or equal to 120 m
Mostly loamy soils	Large industrial facility
Mostly loam-sandy soils	Local or small industrial facility
Gravelly up to stoney soils	Fully operational industrial facility
<u>Human use type</u> •	<u>Distance from major emission source</u> •
Nonrecreational	0 to 3 km
Recreational	3.1 to 6 km
	6.1 to 9 km
<u>Dominant building type</u> •	9.1 to 12 km
Village houses	12.1 km and greater
Apartments	
Town or city houses	
Recreational homes	
Feedlots or barns	
<u>Regions</u> •	
11 Regions	
<u>Land Use</u> •	
Forestry	
Agriculture	
Urban	
Rural	
<u>Human population size of localities</u>	

Since the nesting of the house martin is a function of suitable nest locations on the walls of buildings, density values based on the number of birds per town or per unit geographical area are misleading without information on the number of suitable nesting locations. Comparisons between localities are not possible. To provide a standard measure for nesting density,

recording the number of active or occupied nests per "suitable" side of a building is proposed as basis for comparison of nesting in different localities.

Three measures of population size are recommended: nesting density, colony size and occupancy. Nesting density is defined as the number of active nests per suitable nesting side of a building. This is a measure of the overall nesting response of house martins in a locality. Colony size is the number of active nests per occupied side of building. By averaging the colony sizes for a locality, an average colony size for a locality is determined. Occupancy is a measure of use of a locality by house martins expressed as the percentage of suitable sides with active nests.

A number of ecological and pollution related factors were found to influence the nesting of the house martin. In any bio-indicator sampling program ecological factors need to be considered in evaluating response of the house martin to air pollution. In our study we evaluated 13 major ecological and air quality related factors. These represented 61 subfactors (Tab. 4). A stepwise regression was used to screen these factors and identify which ecological and air quality factors were important in influencing nesting patterns.

RECOMMENDED SAMPLING PROCEDURES

Since house martin shows a preference in its nesting, sampling should occur only in areas with preferred or suitable nesting conditions. Based on our observations and those of other authors, especially LIND (1960, 1964), the following are considered suitable nesting conditions: inhabited buildings, buildings with vertical masonry or stone walls with perpendicular overhangs or eaves, a free or unobstructed flight path of at least 5 meters from the building overhang, away from main roads or heavily travelled highways, and free from anti-nesting devices or evidence of human nest destruction. Sampling should only be conducted on buildings if these conditions exist. In our study we sampled a minimum of 30 buildings with one or more suitable sides. In Czechoslovakia suitable buildings often accounted for only 20 percent of the total number of buildings censused.

As previously described, a standard unit of measure is used in determining nesting values. This standard unit is based in part on a uniform length of suitable building side. In Czechoslovakia the buildings in most localities were primarily rectangular and uniform in dimensions. We adopted a building side length of 20 meters to census (NEWMAN et al., 1985). The number of active nests per 20 meter length of building were counted. Buildings longer than 20 meters, such as apartments, factories, and barns, were divided into 20 meter segments for recording nest numbers. We recommend the use of the 20 meter length or some other comparable unit of length so comparisons between sites or studies can be made.

House martins lay two clutches of eggs per season. In Czechoslovakia the first clutches are laid in May (BALAT, 1976). Active nests are counted and easily distinguished from broken nests or nests occupied by sparrows. Usurpation of house martin nests frequently occurs, especially in the later part of the nesting season. Nests occupied by sparrows are easily distinguished. These nests are often partially broken. The sparrows enlarge the entrances as well as use grass and other nesting materials. These nesting materials are seen hanging out from the inactive house martin nests. The house martin begins flocking towards the end of summer

and active nesting conditions are harder to observe. Sampling should be conducted during the first clutch laying period. The likelihood of abandonment and usurpation is greater during the later stages of the nesting season.

In sampling both ecological and air quality related factors need to be considered. Background and control localities should be similar in distance from water, have similar building type e. g. town houses, apartments, etc; occur in the same region; and have similar human use/land use patterns. Localities use for recreation should be avoided because inhabitants tend to destroy the nest on their homes. Contaminated localities should be similar in wind direction from the emission source.

CONCLUSIONS

Based on its Bio-indicator characteristics and sensitivity to air pollution, the house martin makes an excellent bio-indicator of air pollution in Europe. Its wide distribution allows comparisons between regions as well as different localities in Europe. Because of its association with human environment, its response is diagnostic of the general air quality of the human environment. The relative permanency of its nesting patterns enable it to be used for monitoring or measuring trends in air quality. The ease of sampling and diagnostic response (active vs inactive nests) allows this species for wide use in biomonitoring programs. An air pollution biomonitoring network could be established and coordinated between various countries for evaluating regional conditions and trends.

Future studies recommended include evaluation of the responses of the house martin in other European countries using the proposed sampling procedures to confirm its geographical utility. Studies should also be conducted to correlate the nesting response with given ambient air quality levels.

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Decrease in the clutch size of the black-headed gull (*Larus ridibundus*) as an indicator of the environmental reproduction-toxic potential

Z. ŠVECOVÁ

INTRODUCTION

Birds are suitable model objects for the indication of negative effects of the environment on the reproduction of living organisms. The fact that the birds' embryos develop off the mothers' organisms enable the embryotoxicity of the environment to be detected without having to kill the mother. Data of the fractions of dead embryos in the various developmental stages and frequency of occurrence of various developmental defects can be obtained by analysis of incubated eggs. By examining chicks in the postnatal period we can also observe growth disorder of various kind and retardation of psychomotoric functions, which also are a significant manifestation of embryotoxicity of the environment (JELÍNEK, 1981; PEAKALL, 1985).

The birds' way of living enables us to examine also those reproduction defects that arise from the effect of toxicants on the adult organisms. These include particularly defects in their breeding biology, care of eggs and brood (HARTNER, 1981), which are important factors stimulating the overall breeding success. A lower breeding success can result in a lower frequency of occurrence and ultimately vanishing of the given species from the polluted environment. Detection and identification of all the potential reproduction-toxic agents in a biological material pose problems. All factors contributing to the decrease in the reproduction capability of living organisms are therefore jointly referred to as the reproduction-toxic potential of the environment.

The black-headed gull was elected for the present study. His eggs are easily accessible at breeding colonies. Advantages also include the gull's long life, a favourable position in the food chain and a partial synanthropy, which all make for easier monitoring of the chronic influence of toxic substances and substances of cumulative nature.

In 1987 we observed disorder in the reproduction of the black-headed gull in the surroundings of České Budějovice in South Bohemia, manifested by

1. a high fraction of nests with a reduced clutch size (26 % one-egg clutches, 27 % two-egg clutches and 47 % three-egg clutches);
2. a considerably high frequency of developmental defects in the embryos;
3. a high fraction of eggs with thin shells or even shell-less.

Now, we sought whether the increase in the fraction of clutches of reduced size was a result of the effect of the reproduction-toxic potential of the environment, with a view to employing this index for determining the contribution of this reproduction disorder to the overall population disorder of the black-headed gull at our territory. Comparative analysis of embryonal mortality and occurrence of developmental defects according to RYCHTER et JELÍNEK (1978) was applied to one-egg and three-egg clutches; the treatment relied on

The assumption that one-egg clutches were laid by handicapped females whereas three-egg clutches arose from relatively healthy individuals.

M E T H O D O L O G Y

Eggs were collected from April 10 to May 20, 1988. One egg was taken at random from each three-egg clutch. Previous nest labelling was used when collecting eggs from one-egg clutches to prevent the first egg from an unfinished larger clutch to be picked instead. The eggs were transported to the laboratory where they were analyzed either immediately or in a short time (1 - 2 days) during which they were thermostatted at a temperature of 37.5°C and relative humidity of 60 - 70 %. After opening the egg, the age of the embryo was determined by the method of HAMBURGER (1951) then its vitality and, for embryos older than ten days, occurrence of developmental defects was established. Since for embryos between the 14th and 22nd days of incubation the age could not be determined accurately enough, these were classed in a common group. The state of the embryos' CNS, eyes, faces, limbs, trunks, abdomens, position of cardiac vessels, livers and kidneys (ROMANOFF, 1972) was examined.

Embryos of various age were obtained by the field picking. All embryos from the individual days had to be added together to calculate the mortality and extinction data. Since each embryo had passed all the lower age groups, it was counted in them as well. For instance, an embryo 5 days age was also included in groups of embryos 4, 3, 2 and 1 days old. The number of specimens in the 1st day group thus equals the total number of embryos examined, and the frequency

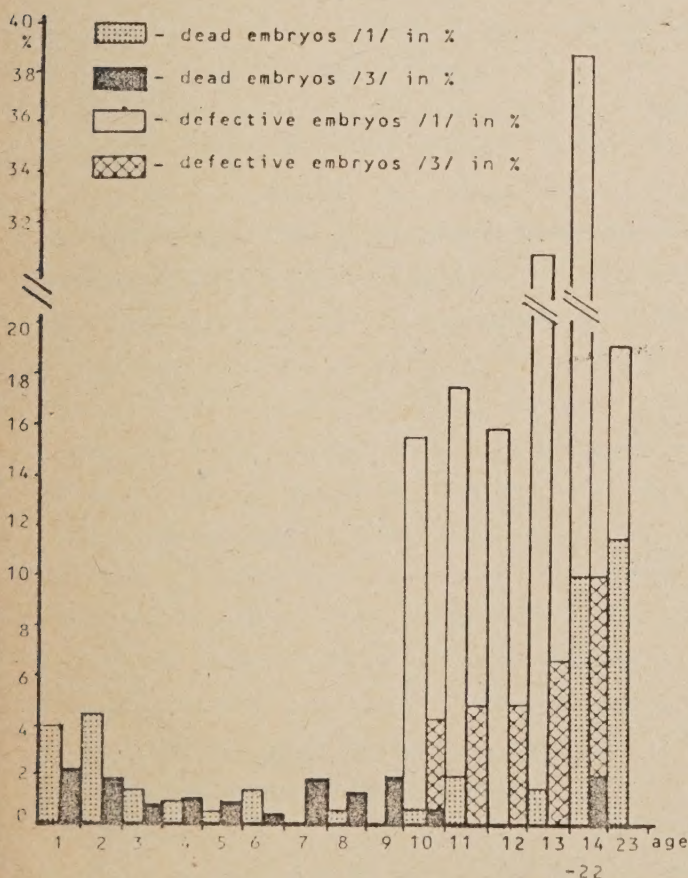


Fig. 1. Distribution of injured embryos in one-egg and three-egg clutches.

Tab. 1. Age distribution of embryos and fractions of dead and injured (= dead + defective) individuals. 1 - one-egg clutches, 3 - three-egg clutches.
 + statistically significant difference at the 5 % significance level ($\chi^2 = 3.84$).
 ++ statistically significant difference at the 1 % significance level ($\chi^2 = 6.63$).

age	1	2	3	4	5	6	7	8	9	10	11	12	13	14-22	23
number of 3 embryos	526	513	501	484	464	451	435	399	374	330	249	189	139	100	7
1	273	250	229	219	212	208	203	188	179	167	154	145	130	111	26
number of 3 dead embryos	11	9	4	5	4	2	8	5	7	2	0	0	0	2	0
1	11	11	3	2	1	3	0	1	0	1	3	0	2	11	3
χ^2	2.5	4.7 ⁺	0.4	0.0	0.3	1.9	3.8	0.7	3.4	0	4.9 ⁺	0	2.2	5.7 ⁺	0.4
n. of injured embryos	3	-	-	-	-	-	-	-	-	16	12	9	9	10	0
1	-	-	-	-	-	-	-	-	-	26	27	23	40	43	5
χ^2	-	-	-	-	-	-	-	-	-	31.7 ⁺⁺	20.4 ⁺⁺	12.8 ⁺⁺	27.9 ⁺⁺	24.3 ⁺⁺	1.6

Tab. 2. Developmental defects in embryos from three-egg (3) and one-egg (1) clutches.

		number of embryos	occurrence of defect	%	χ^2
cystic kidney	3	328	6	1.8	14.1
	1	166	15	9.0	++
"twisted legs"	3	130	0	0	19.7
	1	139	17	13.3	++
synostosis	3	328	5	1.5	4.7
	1	166	8	4.8	+
jaw hypoplasia	3	328	3	0.9	0.7
	1	166	3	1.8	

of occurrence in the age groups decreases with increasing age as far as the ultimate 23 days. (The variability in the incubation time, which is from 21 to 24 days (HUDEC, 1977), is disregarded; the average incubation time to hatching is 23 days.)

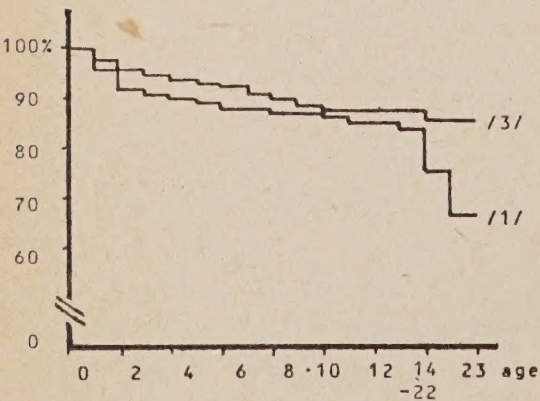


Fig. 2. Extinction of embryos in one-egg and three-egg clutches.

For the two egg collections, the percentage mortality in the individual age groups was determined and the consecutive extinction of embryos in the prenatal period was calculated from it. The statistical significance of differences between the two sets was tested by using contingency tables. Developmental disorder of some kind was evaluated likewise. For expressing the fraction of embryos affected by embryotoxicity, dead and defective embryos were added together (RYCHTER, 1978).

A total of 273 embryos from one-egg clutches and 526 embryos from three-egg clutches were analyzed. Congenital defects were only recorded starting from the tenth day age.

R E S U L T S

The data obtained are given in Tab. 1 and 2. The following developmental defects were most frequently observed: kidney cystose, jaw hypoplasia, limb synostosis and ossification defects of the "twisted legs" type (ANWER, 1986) arising from improper healing of spontaneous fractures.

For the sets of embryos from one-egg and three-egg clutches, statistically significant differences were found in the mortality in the 2nd and 11th days age and in the group of the 14th to 22nd days age. In nearly all age groups, the difference in the frequency of injured (= dead + defective) embryos was statistically significant. The group of embryos 23 days old was an exception but it contained too few specimens for a reliable statistical evaluation.

D I S C U S S I O N

Three-egg clutches are typical of the black-headed gull. In the 1960s, KLÍMA (1964) found 87.8 % three-egg clutches and only 8.8 % two-egg clutches in the South-Bohemian population; he mentions no one-egg clutches whatsoever. YTREBERG (1951) in Norway found that young, one-year old females may sit on one-egg clutches, their fraction, however, was mere 1.9 % whereas the fractions of three-egg and two-egg clutches were 88.4 % and 8.6 %, respectively. Nesting of females one year old was not observed in the South Bohemian population.

Clutch size reduction and eggshell thinning are regarded as a consequence of the adverse effect of chlorinated pesticides, particularly for raptors (HARTNER, 1981), and they are included in the so-called raptor-pesticide syndrome (RATCLIFFE, 1979; NEWTON, 1981). For gulls, this effect as a consequence of environmental pollution has not been as yet observed. The clutch size reduction and eggshell thinning may not be due to the occurrence of chlorinated pesticides solely. In an experiment, such effects have been also observed for various birds after administration of other toxicants, including heavy metals (HEINZ, 1979; FINLEY, 1978; SCHEUHAMMER, 1987). It is assumed that by disturbing her hormonal balance, these substances affect the female's breeding instinct and clutch size (DOBSON, 1981). Theoretically, the clutch size decrease can also be an adaptation response to the higher population density. GRAVES (1984) observed that for herring gulls, increase in the number of breeding pairs is accompanied by a poorer breeding success, i. e. reduction in the number of fledglings per pair. This, however, is actually a consequence of increased postnatal losses caused by lack of food rather than reduction in the clutch size. The fact that in our case, the effect of the reproduction-toxic potential of the environment is really involved, is borne out by the increased mortality and frequency of occurrence of embryos affected by embryotoxicity in the one-egg clutches.

S U M M A R Y

A high fraction of clutches of a reduced size was found in the population of the black-headed gull in the South Bohemia basin. The embryotoxic injury of embryos in eggs from one-egg and three-egg clutches was compared to be sure that no effects other than the reproduction-toxic potential of the environment are involved. The increased mortality of embryos was proved in some critical days of their development. The two groups of embryos exhibited differences in the occurrence of some forms of determined developmental disorder as well as in the total number of embryos affected, starting from the 10th day age that the defect monitoring was commenced. Defects of the twisted legs type were observed in embryos from the one-egg clutches solely. Although the cause of the defects observed (reduced clutch size, increased mortality and frequency of developmental defects) was not sought, this ossification defect is apparently due to disturbance of the calcium metabolism in the developing embryo (ONO, 1986). Towards the end of the incubation period, defects caused by embryotoxicity of the environment were observed in 40 % embryos from the one-egg clutches as against the 10 % embryos from the three-egg clutches. The fraction of one-egg clutches from the total can be probably employed as an index for assessing the extent of this reproduction disorder in the population of the black-headed gull at a particular site on the territory of Czechoslovakia.

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Small mammals as indicators of environmental mutagenesis

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The ever-increasing environmental pollution leads to looking for and improving the methods facilitating the monitoring of quantitative and qualitative characteristics of the environment and providing a basis for risk inference. The evaluation of mutagenic environmental factors is more difficult than the study of most other noxious effects. Many pieces of knowledge have been accumulated by the experimental studies dealing with mutagenic properties of various physical and chemical agents (cf. HSU, 1982; HEDDLE, 1982). Monitoring of genetic consequences in populations potentially exposed to environmental agents displaying mutagenic properties has been conducted primarily in man and domestic animals (CHRISMAN, 1980; BENDER, 1981; CONNER, WALD, 1981; LOJDA, 1982; LÉONARD et al., 1985), and relatively few investigations have been concerned with the study of heritable damage in free-living organisms.

Various plant groups and species have been used to monitor mutagenic hazards created by the effects of air pollution (KORYTOVA, 1983), industrial pollution (DUCHAREV et al., 1984, DRUŠKOVIC, 1987), or by the use of pesticides (KURINNYJ, 1985). Invertebrates have been only rarely utilized as biological indicators of environmental mutagenesis (e.g. DIXON, 1982). In vertebrates, the mutagenic effects have been evaluated in natural populations of fishes (KLINGERMANN in HSU, 1982; VAN DER GAAG, VAN DE KERKHOFF, 1985; STĚPANOVA, 1987), amphibians (JELISEJEVA et al., 1985b) and birds (ELLENTON, McPHERSON, 1983). Mammals appear to be the most important vertebrate class in this respect.

The purpose of this contribution is to present a review of current knowledge of the action of mutagens in natural mammalian populations, and to evaluate the perspectives of further research and utilization of its results.

WILD MAMMALS AS A TEST MODEL

Methodical sources for the assessment of presumed mutagenic effects in free-living mammals can be taken over with advantage from studies dealing with man and domestic or laboratory animals. The possible means of detecting the mutagenic action can inhere in the registration of deviant phenotypes (congenital defects, sperm morphology, tumor markers), detection of the production of gene mutations and/or chromosome aberrations scoring, in the study of indicators of the reproductional success, or in the determination of the mutagenic potentialities of body fluids via standard bacterial mutagenicity assays, i.e. determination of the levels of mutagens present in the body. From the practical point of view of direct bioindication, cytogenetic assays probably represent the most convenient method. The cytogenetic tests may be employed in the evaluation of the occurrence level of unstable chromosome aberrations or sister chromatid exchanges, in micronucleus testing in somatic cells, as well as in the study of the frequency of chromosomal abnormalities in germ cells or of the occurrence of specimens with an anomalous karyotype in population samples. The selection of test species or test population is usually dependent on sample size requirements. In this respect, small mammals, especially rodents are

Tab. 1. Chromosomal aberrations in *Microtus arvalis* from 7 localities in Czechoslovakia. Localities no. 1-5 are situated in heavily polluted area (northern Bohemia), localities no. 6 and 7 control sites (southern Bohemia and southern Moravia) (after ZIMA, 1985).

Locality	Number of individuals	Number of cells	Mean number aberrant cells per individual
1	5	500	0.8
2	5	500	0.6
3	5	500	1.0
4	5	500	1.6
5	5	500	1.4
6	12	1 200	1.1
7	13	1 300	1.2

the most advantageous objects. The utility of this animal group can be seen also in their small space mobility, and often narrow ecological niches.

The first information about possible genetic damage caused by mutagens in the external environment were obtained in South India, in areas embracing a high level of natural activity (GRÜNEBERG et al., 1966). BORODKIN (1985) investigated the effects of environmental mutagens on the aneuploidy frequency and the level of mitotic activity in the voles of the genus *Clethrionomys*. ROSS (1986) studied experimentally the manifestation of radiation effect in genetic changes and population processes in voles. Chromosomal aberration frequencies in the cells of specimens originating from natural populations were scored by CRISTALDI et al. (1985), JELISEJEVA et al. (1985a), ZIMA (1985), and MCBEE et al. (1987). The micronucleus test was used in free-living mammals by LUKE et al. (1984) and PARADISI et al. (1986). Only relatively few data were gathered on the neoplastic diseases in free-living mammalian populations (e.g. HENRIQUEZ, 1985).

CHROMOSOMAL ABERRATIONS IN SOMATIC CELLS

The frequency of chromosomal aberrations has so far been studied only in the bone marrow cells of free-living mammals. Our results have shown that the spontaneous level of chromosomal aberrations in free-living mammals is comparable with that in man and laboratory or domestic mammals. No substantial differences have been manifested in the spontaneous aberration frequency between species belonging to various systematic and ecological groups (ZIMA, 1981, 1985). We have not found any significant differences in chromosomal aberration levels between population samples of voles captured in the regions exposed to various degrees of industrial and agricultural pollution (see Tab. 1), but CRISTALDI et al. (1985) and MCBEE et al. (1987) demonstrated an increased rate of aberrations in rodents living in habitats polluted with a complex mixture of mutagenic substances. Similarly, PARIDA et MOHAPATRA (1986) observed a multiple increased frequency of damaged chromosomes in free-living rats from the areas characterized by a high level of natural radiation in the Kerala State of South India. An increase in aberrations was documented in rodent populations in contaminated localities also in studies adopting the micronucleus test, counts of sperm abnormalities, and some other methods (CRISTALDI et al., 1985; PARADISI et al., 1986).

CHROMOSOMAL MUTATIONS IN GERM CELLS

Abnormal karyotypes in zygotes result from chromosomal mutations in germinal cells. Unbalanced karyotypes, showing lack and/or excess of a part of euchromatic chromosome material, often cause spontaneous abortion and only a small portion of anomaly carriers (usually afflicted by severe defects) survive in the postnatal period. The balanced rearrangements need not inflict any harmful somatic effects. In human populations, chromosome abnormalities have been found in the karyotype of 30 to 60 % of abortions, and in 0.5 - 0.7 % of newborn infants (HSU, HIRSCHHORN, 1977; DEJMEK, 1978). The determination of similar frequency parameters in free-living populations is rather difficult owing to the still insufficient amount of factual data. In an earlier paper (ZIMA, KRÁL, 1982), we have estimated the frequency of occurrence of specimens with an abnormal karyotype originated through a new mutation in free-living mammalian populations at 0.1 - 0.3 %.

In a recently evaluated sample (about 1 700 specimens of 80 species), I have found an abnormal karyotype in 6 specimens. Numerical anomalies in sex chromosomes have been observed in four cases. The species affected included the common vole, Microtus arvalis (45, X0; 47, XXY; 47, XYY) and the pipistrelle bat, Pipistrellus pipistrellus (43, presumably X0). The frequency of occurrence of these unbalanced anomalies was 0.24 % in the whole sample, but in the only species (Microtus arvalis) it reached 1.4 %. No visible somatic defects have been found in the specimens afflicted, but they were all reproductively inactive. In two specimens of Apodemus flavicollis and Microtus agrestis, I have ascertained heterozygous Robertsonian fusions of non-homologous autosomes. This type of karyotype variability is quite unusual in both species, and this fact suggests the possible origin of the rearrangements de novo. Including these two cases, the frequency of specimens possessing presumably new mutations in their karyotypes was 0.35 % in the sample evaluated.

POTENTIAL EVOLUTIONARY CONSEQUENCES OF THE MUTAGENIC PRESSURE

Most of the changes caused by mutagenicity bring about unfavourable consequences for organisms and are rapidly eliminated by natural selection. Certain changes can be advantageous, however, and they can enter the evolutionary processes. Increased mutagenic pressure may lead to the acceleration of karyotypic evolution, and to the origin of polymorphous populations, polytypic species, and karyotype races. YOSIDA et PARIDA (1980) assumed that the mutagen effects in the areas of high natural radiation in South India might stimulate the origin of several new mammalian species as a consequence of their intensive karyotype divergence. .

To test this hypothesis, I have compared the extent of intrapopulational and intraspecific karyotype variability between several samples of free-living mammals from various geographical regions. The ascertained cases of variation were caused by Robertsonian rearrangements, pericentric inversions, heterochromatin deletions (duplications, and the occurrence of supernumerary chromosomes). All cases of variation evaluated were probably maintained in populations and transmitted from one generation to another. Certain differences between samples were manifest (Tab. 2).

Tab. 2. Percentage occurrence of karyotypically variable species and specimens with rearranged karyotype originated from polymorphic populations in samples from various geographical areas. S = number of species examined; P = number of karyotypically variable species; N = number of specimens examined; H = number of specimens with rearranged karyotype.

region	S	P	%	N	H	%
northern Bohemia	10	4	40.0	234	35	15.0
southern Bohemia, the Šumava Mts.	24	3	12.5	193	7	3.6
southern Moravia	34	6	17.6	294	48	16.3
the Tatras	20	4	20.0	456	47	10.3
the Balkans	18	6	33.0	117	7	6.0

METHODOLOGICAL PROBLEMS

The interpretation of the results obtained in cytogenetic studies using wild mammals as test objects is complicated by a variety of methodological difficulties. The results may be influenced already by the chromosome preparation method itself, or by the choice of the tissue selected for examination. A preferable preparation technique, especially in small mammals, seems to be the direct treatment of bone marrow cells. The problems with artifacts, which sometimes occur in cell cultures grown for karyotyping, are not topical in bone marrow assays. The evaluation and classification of individual unstable chromosome aberrations is still not completely unified, and a direct comparison of the results obtained in different laboratories is often difficult.

In the case of the finding of an increased level of chromosomal aberrations in a natural population, it is generally difficult to determine the responsible factor explicitly, because various causes can lead to the same consequence. The increased aberration level can be provoked by certain effects not at all related to anthropogenic pollution of the environment by mutagens. In this respect, the effects of virus infections have to be especially considered. The possibility of greatly variable population density must be taken into account, particularly in rodents. In the period of peak numbers, the increased level of chromosomal aberrations can be produced, for instance, as consequence of the stress conditions spreading in the population (cf. SKOROVA et al., 1986).

Species heterogeneity of material studied provides a very important problem. It is useful to select preferably common and euryecious species as the test model in the monitoring of mutagenic effects, because such species can be trapped in sufficient numbers in the localities of interest. Different species are then understandably selected for examination in various geographical regions, and possibility of using a universal model is practically excluded. In spite of the absence of major differences in spontaneous incidence of somatic chromosome aberrations, it is necessary to make allowance for specific genetic responses to mutagenic pressure. This specificity may be conditioned either secondarily by foraging strategy and habitat requirements of individual species, or primarily by differential susceptibility of somatic and germ cells, resulting from specific metabolic conversion into mutagens, specific regulation of DNA repair processes and so on (cf. LÉONARD et al., 1982; NATARAJAN et al., 1982; HART, CHANG, 1983).

The results of McBEE et al. (1987) actually confirmed the differences in chromosomal lesion frequencies between two rodent species inhabiting syntopically a habitat contaminated by mutagenic substances. The validity of extrapolations of the results obtained in natural populations to the possible risks for their species or for human population is therefore questionable.

There are very few data concerning the adaptive capability of free-living mammals in the conditions of long term chronic exposure to low doses of mutagens. Adaptive mechanisms are apparently not able to compensate for an acute exposure to very high doses of mutagens, but particularly in species with rapid turnover of generations, the possibility of gradual selection of resistance should be seriously considered. Cytogenetic short-term tests do not adequately reflect the chronic exposure and this circumstance further complicates the extrapolation of results to other species.

Problems associated with comparing different species are growing in the considerations of the occurrence of mutations in germ cells. The information obtained by the study of the incidence of specimens with an abnormal karyotype in free-living populations provides only a rough estimate and the utilization of this knowledge in the monitoring of mutagenic effects is very wide to-date. The same holds for the comparison of intrapopulation and intraspecific karyotype variability levels. The objectivity of this evaluation is evidently very low in considerations dealing with specifically heterogeneous samples. The characteristics of intraspecific karyotype variability and the chromosome polymorphism dynamics are apparently affected by many factors not related to mutagenesis.

C O N C L U S I O N S

Despite many methodological problems, I suppose that free-living mammals could serve as useful bioindicators of environmental mutagenic effects. The problems discussed taken all in all are often topical even in the studies of mutagenic hazard in human, domestic and laboratory animal populations. The results obtained in resident wildlife populations might provide various items of information which would not be obtainable by testing of human or laboratory animal and these data could extend and enrich our comprehension of problems associated with anthropically conditioned environmental mutagenesis. The most practically applicable test method is currently presented by the evaluation of the level of chromosome aberrations in somatic cells (including the micronucleus test and sister chromatid exchange studies). Rodents are the most utilizable test models; in the selection of the species tested possible interspecific differences should be taken into account. It would be useful to obtain data on potential effects of mutagenic environmental agents on the genetic diversity of rare and endangered species. The cytogenetic studies in free-living mammals should be purposefully combined with the application of other test systems of mutagenic risk assessment as well as with extensive ecological research of the areas of interest.

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Blood cholinesterase activities in natural and experimental population of Rodentia after an exposure to organophosphates

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The terrestrial environment monitoring can utilize (with some restrictions) several biochemical methods routinely used in laboratory experiments of industrial hygiene (MARGOTTI et al., 1987; RYHANEN et al., 1984; NIETHAMMER, BASKETT, 1983). For our pilot study in the ecotoxicological area two specific enzymatic tests of cholinesterases (CHE) were chosen. They were selected from a larger set of biochemical tests, which were originally introduced for diagnostic purposes after mass intoxications, eg. after chemical accidents etc. (HLAVÁČEK et al., 1982).

Erythrocyte Acetylcholinesterase E.3.1.1.7. (ACHE) in blood samples and Plasma Cholinesterase E.3.1.1.8. (PCHE) are specifically inhibited by organophosphates (OP) widely used in agriculture (pesticides etc.). The main task of the study was the methodology of detection of OP in the environment by determining the effects of OP on small wild mammals. The second task concerned the additional effects of immisions in heavily polluted areas on CHE and other simultaneously measured variables (somatometric, hematological, morfological deformations of sperm cells etc.).

In healthy animals the activity of PCHE informs about the degree of proteosynthesis in the liver parenchyma. The processes leading to reduction of functional liver parenchyma affect the concentration levels of serum albumin (ALB) and PCHE. On the contrary, exposures to OP tends to inhibit CHE only, which can be used as an sensitive indicator of the degree of pesticide-poisoning. The measurement of both ACHE and PCHE is of advantage because the intensity (dose) and duration of OP exposure influence to some extent the relative ratio of ACHE and PCHE activity:

Type of intoxication	PCHE (%)	ACHE (%)
Acute light	50 - 70	75 - 100
Acute heavy	0 - 10	25 - 50
Chronical light	75	80
Chronical heavy	25	25 - 40

METHODS

Two types of modified electrometric (pH metric) methods for ACHE and PCHE (DOLEŽAL et al., 1985) and the standard clinical photometric method for PCHE (WHITTAKER, 1984) were used.

Between PCHE methods (electrometric and photometric) there was a high correlation ($r = 0.95$, $N = 216$) and both were replaceabel irrespective of the difference in the substrate they use (acetylcholinchlorid, butyrylthiocholin). The correlation between ACHE and PCHE methods was not so tight ($r = 0.57$, $N = 208$), the methods inform about different fractions of cholinesterases. Results of electrometric methods can be presented in the relative units (%) (compared with standard values etc.) in the arbitrary units, eg. (pH) or according to our experience they can be recalculated to international units (microcatal) by the formula:

$$\text{CHE (mikrocatal)} = \text{CHE (pH)} \cdot F / K$$

Tab. 1. Activities of cholinesterases - *Microtus arvalis*. N - natural environment (meadow, reservation, reclaimed land), A - agrochemically treated fields (alfalfa growth).

Region	Type	Local.	N	ACHE (pH)	SD	N	PCHE (μkat)	SD
North B.	N	Most 1	24	34.2	6.4	33	31.3	21.7
North B.	N	Most 2	15	42.2	4.4	15	42.7	16.3
North B.	A	Most-V	20	42.8	5.4	20	46.6	12.7
South B.	A	Tisy-V	40	30	6.8	40	24.6	16.0
South B.	A	Aurora	20	41	4.6	20	46.1	11.2
Central B.	A	Sluhy-V	39	30.9	6.4	39	20.6	13.7
Central B.	N	Zapy	18	42	6.5	18	45.2	24.8
Central B.	N	Sarka	24	34.1	4.9	24	45.2	22.0
Experim.	Standard		20	47.1	5.8	20	35.2	13.7
Experim.	Intox.		10	13.3	3.6	10	3.7	0.44

where F is constant of certain method (ACHE/PCHE) including volumes of reagents and enzyme and incubation time, and K is the buffer capacity factor from titration of buffer by acetic acid. For our modified methods $F\text{ (PCHE)} = 83.33$, $F\text{ (ACHE)} = 13.89$, $K\text{ (PCHE)}$ is cca 1.2 (pH/μmol) and $K\text{ (ACHE)}$ is cca 7.7 (pH/μmol).

RESULTS

Animals were captured in three regions (North, South, Central Bohemia) differing in the degree of industrial immisions. In each region two types of location were selected: 'natural' (N) meadows without any direct agrochemical impact and potentially 'agrochemically' (A) treated fields of alfalfa. After the field study simple lab. experiments on 'Standard' population were performed simulating (roughly) the situation of OP treatment of fields ('Intoxication' by spray of Fenitrothion 0.3 ml . m⁻². Data from the localities and experiments are presented in Tab. 1.

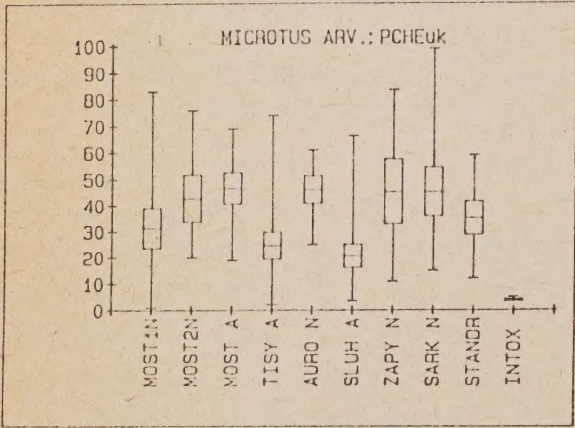


Fig. 1. Activities of Acetylcholinesterase (ACHE) of *Microtus arvalis* in 'natural' (N), 'agrochemically' (A) treated fields and experiments (standard, Intox.).

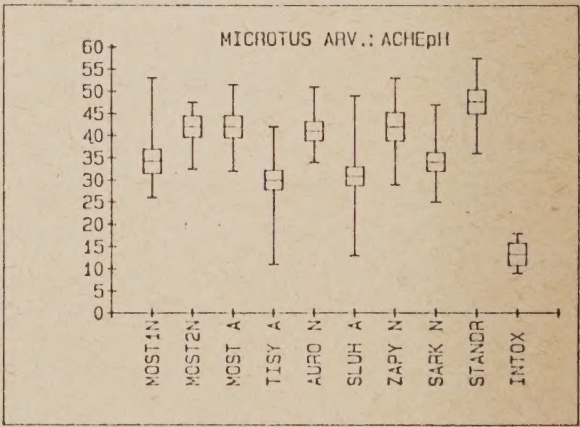


Fig. 2. Activities of Plasma Cholinesterase (PCHE).

The situation and relationship between localities are shown in Fig. 1 (ACHE) and Fig. 2 (PCHE). Boxes constructed as the 95 % confidence limits of the means can be used for 'simultaneous testing' of differences between samples. Whiskers show the minimum and maximum values in the sample.

Most localities without ACHE inhibition belong to 'natural' locations and, on the contrary, two of tree 'alfalfa' fields exhibit depression of ACHE and PCHE. There are also some unexpected results like the depression of ACHE (but not PCHE) in the reservation Sarka, and low ACHE activities in excessively polluted locality Most 1 in the vicinity of a chemical plant. No inhibition in locality Most-V (alfalfa) can be ascribed to longer period after treatment (late autumn).

From the generalized statistical point of view the differences of both ACHE and PCHE between two types of localities (natural/agricultural) are highly significant and show deeper inhibition of cholinesterases in agriculturally exploited localities:

ACHE 'alfalfa' (32.9), 'natural' (38.2) ($t = 5.2$, $N = 189$, $p < .001$)

PCHE 'alfalfa' (27.5), 'natural' (40.0) ($t = 4.9$, $N = 217$, $p < .001$)

Results from our small pilot study show usefulness of CHE methods in the biological monitoring of OP in the environment. The study created good foundations for a more complex field research in the future.

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Belastung durch Fluorid im Trinkwasser - Zusammenhang mit Krebs und Leberzirrhose

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E I N L E I T U N G

Trinkwasser enthält von Natur aus zahlreiche Substanzen, darunter Fluorid. Seit Jahrzehnten wird das Trinkwasser vieler Orte zur "Kariesvorbeugung" mit Fluorid auf eine Konzentration von 1.0 ± 0.1 ppm künstlich angereichert. Die Wirksamkeit dieser Massnahme gegen Karies ist seit Jahren wissenschaftlich umstritten [1-7]. Seit 1975 sind auch massive Bedenken hinsichtlich eines möglichen Zusammenhanges zwischen Fluoridierung und Krebs dazugekommen [8-17].

In der folgenden Analyse wird die Frage eines Zusammenhanges zwischen Trinkwasserfluoridierung, Krebs und Leberzirrhose anhand amtlicher amerikanischer Daten mit bewährten statistischen Methoden (Regressionsanalysen) und Modellen weiterführend untersucht.

M E T H O D E

Es ist bekannt, dass Krebs viele Ursachen hat und die Mechanismen seiner Entstehung und Beeinflussung in vielen Bereichen noch unbekannt sind. Ferner ist bekannt, dass Fluoride schon in sehr kleinen Konzentrationen zahlreiche Enzyme hemmen und in den Stoffwechsel eingreifen können [18]. Ausserdem ist bekannt, dass zahlreiche Fluorverbindungen krebserregend sind oder die krebserregende Wirkung anderer Substanzen verstärken können [19,20]. Daher stellt sich die Frage, ob auch der Zusatz von Fluoriden zum Trinkwasser in irgend einem Zusammenhang mit dem Krebsgeschehen steht oder nicht. Burk und Yiamouyiannis fanden bereits eine höhere Krebstodesrate in fluoridierten US-Grossstädten gegenüber unfluoridiert gebliebenen US-Grossstädten, wobei beide Städtengruppen vor Beginn der Fluoridierung vergleichbare Krebstodesraten aufwiesen [8, 10]. Dem wurde von anderer Seite (National Cancer Institute of the USA, und andere) widersprochen, das Problem ist jedoch nach wie vor wissenschaftlich ungeklärt [9]. Die folgenden Analysen stützen sich auf noch umfangreichere amtliche Daten und gehen von anderen Überlegungen und Modellansätzen aus.

Die Einführung der Trinkwasserfluoridierung hat stets zur Folge, dass sich für die davon betroffene, mehr oder weniger grosse Zahl von Menschen plötzlich die Lebensbedingungen in dem einen Faktor "Fluorid" verändern, wobei der "neue Zustand" ("Fluorid mit 1 ppm im Trinkwasser") viele Jahre anhält. So wurde im Jänner 1945 mit der künstlichen Trinkwasserfluoridierung in den USA in Grand Rapids, Mich., (165 000 Einwohner) begonnen. 1949 erhielten 1.06 Mio Einwohner oder 0.71 %, im Jahre 1970 bereits 84.7 Mio Einwohner oder 41.7 % der US-Bevölkerung mit Fluorid auf 1 ppm ($1 \text{ mg F}^-/\text{l}$) angereichertes Trinkwasser [21].

Das Problem ist nun, den möglichen Einfluss des Faktors "Fluorid" vom Einfluss der anderen, weitgehend unbekannten Faktoren auf das Krebsgeschehen zu isolieren, sofern ein "Fluorideinfluss" überhaupt besteht bzw. dieser hinreichend gross ist, um festgestellt werden zu können. Man kann zunächst davon ausgehen, dass nicht alle Menschen gegen Fluorid die gleiche Empfindlichkeit aufweisen. Wenn es aber eine Gruppe "fluoridempfindlicher" Menschen im Hinblick auf das

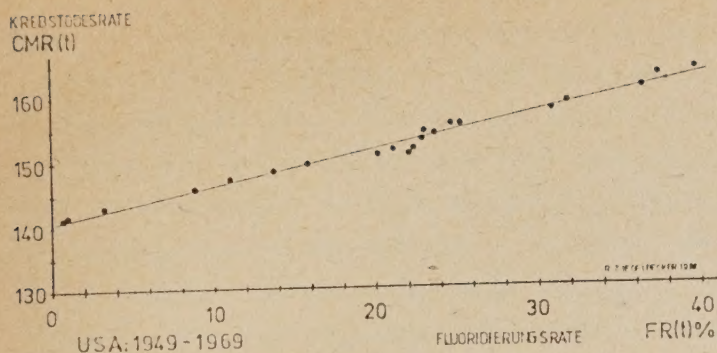


Abb. 1. Relation zwischen Krebstodesrate und Fluoridierungsrate in den USA.

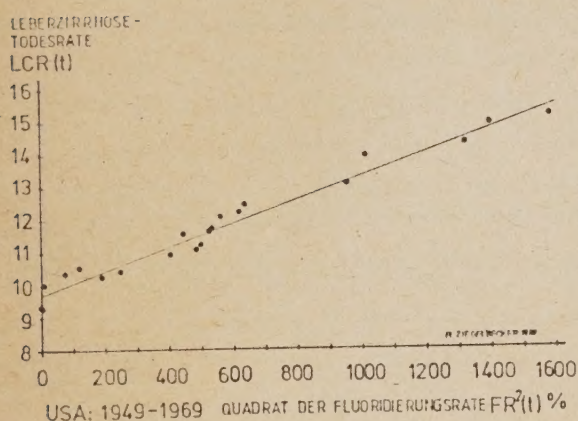


Abb. 2. Relation zwischen Leberzirrhose-Todesrate und Fluoridierungsrate in USA.

Krebsgeschehen gibt, so befindet sich diese unter der Gesamtheit der fluoridierten Einwohner und damit ein Teil davon möglicherweise auch unter den Krebstoten. Die folgenden Analysen zielen daher darauf ab, festzustellen, ob ein Zusammenhang zwischen der Anzahl bzw. dem Anteil der fluoridierten Einwohner der USA und den Krebs- bzw. Leberzirrhosetodesfällen in den USA feststellbar ist oder nicht.

Der erste Modellansatz geht davon aus, mittels Regressionsanalyse festzustellen, ob zwischen der Fluoridierungsrate (Prozentsatz der fluoridierten US-Bevölkerung) und der Krebstodesrate, der altersgewichteten Krebstodesrate, der Leberzirrhosetodesrate, der altersgewichteten Krebstodesrate und der Leberzirrhosetodesrate über einen Zeitraum von rund 20 Jahren (1949 - 1969) signifikante Zusammenhänge bestehen oder nicht. Dieser Zeitraum ist deshalb für die Analyse besonders aktuell, weil sich einerseits die Trinkwasserfluoridierung zwischen 1949 und 1969 in den USA am stärksten ausgebreitet hat und weil andererseits in dieser Zeit die Krebsvorsorge, Früherkennung, und Krebsbehandlung (chirurgisch, chemisch, Bestrahlung), welche die Krebstodesraten beeinflussen können, noch nicht so entwickelt waren.

Der zweite Modellansatz geht von der Tatsache aus, dass sich die Fluoridierung zwischen 1949 und 1969 in den USA sehr unterschiedlich ausgebreitet hat. Es gibt Zeiten, wo sie nur langsam vorangeschritten ist, und solche, wo es "Fluoridierungsschübe" gegeben hat, d. h. wo plötzlich sehr viele US-Einwohner Fluorid ins Trinkwasser bekommen haben. Ob fluoridiert wurde oder nicht, hängt von sehr vielen im einzelnen nicht erfassbaren Faktoren ab, die man weitgehend als zufällig ansehen kann. Wenn überhaupt eine Chance besteht, unter den vielen Einflüssen auf das Krebsgeschehen einen allfälligen Einfluss des Faktors "Fluorid" feststellen zu können, dann am ehesten im Falle eines "Fluoridierungsschubes", wo plötzlich eine sehr grosse Zahl von

Menschen - darunter natürlich auch eine dementsprechend grosse Zahl von "fluoridempfindlichen" Menschen mit Fluor-Chemikalien im Trinkwasser behandelt wurde. Es stellt sich daher die Frage, ob ein "Fluoridierungsschub", d. h. ein grosser Zuwachs an neu fluoridierten Menschen mit einem dementsprechenden Zuwachs an zusätzlichen Krebstoten verbunden ist oder nicht. Besteht ein solcher Zusammenhang, so heisst dies natürlich noch nicht unbedingt, dass Fluorid kurzfristig neuen Krebs erzeugt, der rasch zum Tode führt. Sondern es kann auch sein, dass Leute betroffen sind, die schon Krebs haben und dieser mobilisiert wird; oder dass andere Vorgänge bei Krebskranken unter Fluorideinfluss (etwa auf den Stoffwechsel, Enzymhemmung, Schwächung des Immunsystems, etc.) zum Tode führen.

Unter diesen Gesichtspunkten werden nachfolgend amtliche Daten über die Entwicklung der Trinkwasserfluoridierung und der Krebs- sowie Leberzirrhosetodesraten in den USA im Zeitraum 1949 - 1969 analysiert [21 - 23].

ERGEBNISSE UND DISKUSSION

Zunächst werden die Fluoridierungsrate $FR(t)\%$ (Prozentsatz der fluoridierten US-Bevölkerung im Jahre t) und die Krebstodesrate $CMR(t)$ (Krebstote pro 100 000 Einwohner im Jahre t) über den

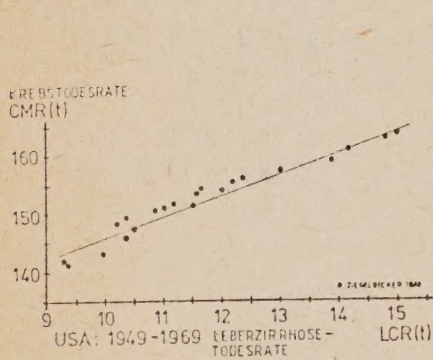


Abb. 3. Relation zwischen Leberzirrhose-Todesrate und Krebstodesrate in den USA.

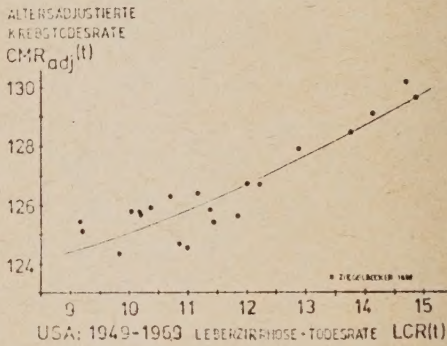


Abb. 4. Relation zwischen Leberzirrhose-Todesrate und altersgewichteter Krebstodesrate in den USA.

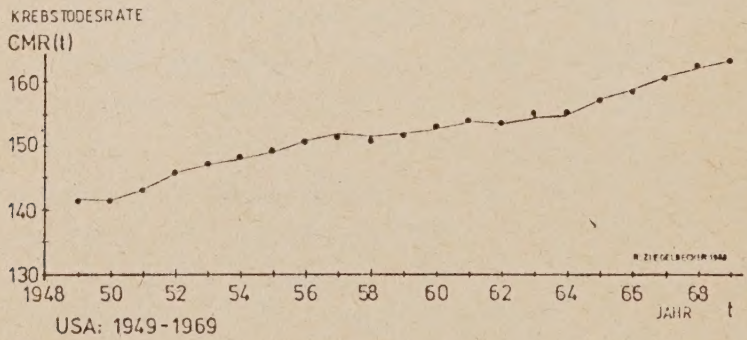


Abb. 5. Relation zwischen Fluoridierungs- und Leberzirrhose-Todesrate mit der Krebstodesrate 1949 - 1969 in den USA.

Zeitraum 1949 - 1969 in Relation gesetzt (Abb. 1). Der dargestellte lineare Zusammenhang ist hochsignifikant. Die Regressionsanalyse ergibt: $b_0 = 140\,557$, $b_1 = 0.556$, $R^2 = 0.983$, $F = 1088.9$, $s^2 = 0.729$, $n = 21$. Die Krebstodesraten sind auf die 6th Revision der Krebsstatistik und als $CMR(t) = CM(t)/E(t-1)$ berechnet (E = Einwohnerzahl, t = Jahr). Bei der Fluoridierungsrate ($FR(t) = F(t)/E(t)$ (F ... fluoridierte Einwohner im Jahre t) wurde berücksichtigt, dass Alaska und Hawai erst 1959/60 in die US-Krebsstatistik aufgenommen wurden (CMR = Cancer Mortality Rate; CM = Cancer Mortality).

Als nächstes wird der Zusammenhang zwischen Fluoridierungsrate und Leberzirrhose-Todesrate untersucht. Abb. 2. zeigt, dass die Leberzirrhose-Todesrate in den USA zwischen 1949 und 1969 mit dem Quadrat der Fluoridierungsrate wächst. Der dargestellte Zusammenhang ist hochsignifikant. Die Regressionsanalyse ergibt: $b_0 = 9.729$, $b_1 = 0.00359$, $R^2 = 0.966$, $F = 547.6$, $s^2 = 0.102$, $n = 21$. Die Todesraten sind auf die 6th Revision als $LCR(t) = LC(t)/E(t-1)$ berechnet.

Die nächste Frage stellt sich nach dem Zusammenhang zwischen der Leberzirrhose-Todesrate und der Krebstodesrate bzw. der altersgewichteten Krebstodesrate. Diese Frage ist schon deshalb aktuell, weil einerseits die Leber als Entgiftungsorgan fungiert und andererseits Fluoride zahlreiche Enzyme in der Leber hemmen können. Die Abb. 3 und 4 zeigen die entsprechenden Relationen.

Die dergestellten Zusammenhänge sind hochsignifikant. Die Regressionsanalysen ergeben zu Abb. 3: $b_0 = 109.484$, $b_1 = 3.638$, $R^2 = 0.945$, $F = 328.1$, $s^2 = 2.327$ zu Abb. 4: $b_0 = 121.385$, $b_1 = 0.0372$, $R^2 = 0.834$, $F = 95.5$, $s^2 = 0.493$.

Auf Grund der bisherigen Ergebnisse wird nun der Zusammenhang zwischen der Fluoridierungsrate und der Leberzirrhose-Todesrate mit der Krebstodesrate in einem multiplen Regressionsmodell untersucht (Ansatz: $CMR = b_0 + b_1FR + b_2LCR$). Abb. 5 zeigt das Ergebnis für den Zeitraum 1949 - 1969 in den USA. Die Punkte sind gemessen (Datenpunkte nach den US-Statistiken), die Kurve wurde mittels Regression berechnet.

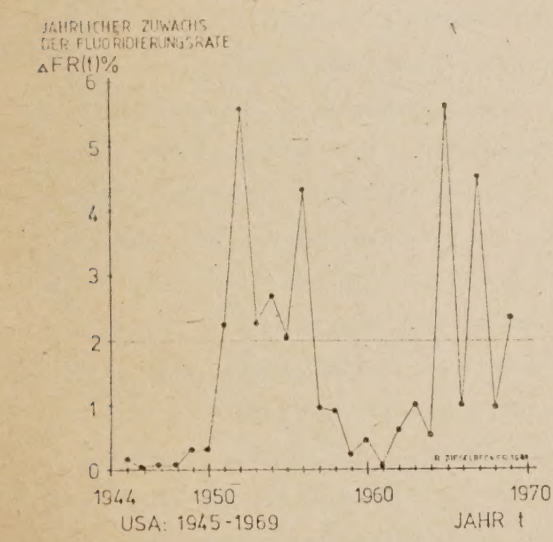


Abb. 6. Jährliche Zuwächse der Fluoridierungs-raten 1945 - 1969 in den USA.

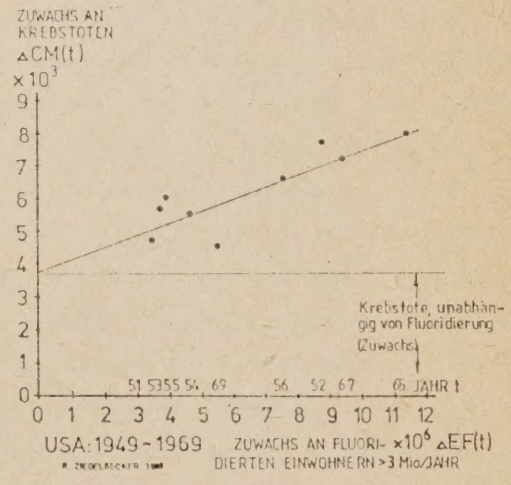


Abb. 7. Relation zwischen dem Zuwachs an fluoridierten Einwohnern und dem Zuwachs an Krebstoten 1949 - 1969 in den Jahren von "Fluoridierungsschüben" in den USA in Zeiten starken Neufluoridierung.

Der dargestellte Zusammenhang ist hochsignifikant. Die Regressionsanalyse ergibt: $b_0 = 130.488 \pm 2.274$, $b_1 = 0.392 \pm 0.0386$, $b_2 = 1.150 \pm 0.258$, $R^2 = 0.992$, $F = 1096.5$, $s^2 = 0.365$, $n = 21$. Die Todesraten sind wieder auf die 6th Revision bezogen, die Aufnahme von Alaska und Hawai 1959/60 in die US-Statistik ist berücksichtigt.

Nachfolgend wird nun das Problem unter den Gesichtspunkten des zweiten Modellansatzes untersucht:

Zunächst wird festgestellt, in welchen Jahren es zu Fluoridierungsspitzen ("Schüben"), d.h. zu einem aussergewöhnlich hohen Zuwachs an neu fluoridierten US-Einwohnern gekommen ist. Abb. 6 zeigt den jährlichen Zuwachs der Fluoridierungsraten $\Delta FR(t)\%$. Als Kriterium für "hohen" Zuwachs wird die 2 % - Marke gewählt, d. h. es werden zunächst jene Jahre betrachtet, in denen die fluoridierten Einwohner um zwei oder mehr Prozent der US-Bevölkerung zugenommen haben.

Zuwächse über 2 % waren in den Jahren 1951 - 1956 und 1965, 1967, 1969 gegeben. In diesen Jahren stieg die neu fluoridierte Bevölkerung jeweils um mehr als 3 Mio Einwohner an. Diese Jahre sind daher Gegenstand der folgenden Analyse. Im folgenden wird untersucht, ob der absolute Zuwachs der Anzahl der fluoridierten Einwohner $\Delta EF(t)$ mit dem absoluten Zuwachs an Krebstoten $\Delta CM(t)$ in einem Zusammenhang steht oder nicht. Aus Abb. 7 ist ersichtlich, dass ein solcher Zusammenhang besteht.

Der Zusammenhang ist mit 99.7 % (F-Statistik) signifikant. Die Regressionsanalyse ergibt: $b_0 = 3854.697 \pm 569.76$, $b_1 = 0.000373 \pm 0.0000805$, $R^2 = 0.755$, $F = 21.5$, $s^2 = 440197.774$, $n = 9$.

Somit ist jeder "Fluoridierungsschub" in diesen Jahren auch von einem "Schub" an Krebstoten begleitet. Auf 10 000 neu fluoridierte Einwohner der USA entfallen nach obigem Ergebnis etwa 3.7 zusätzliche Krebstote. Der Neuzuwachs an Krebstoten beträgt ohne Neufluoridierung ca. 3850 im jährlichen Durchschnitt.

Auf welche Weise Fluorid hier kurzfristig in das Krebsgeschehen eingreifen könnte, ist bisher unbekannt und sollte Gegenstand weiterer Untersuchungen sein. Zu einem noch stärkeren Zusammenhang zwischen neu fluoridierten und krebstoten Einwohnern kommt man, wenn man eine Zeitverschiebung von etwa 3 Monaten zwischen den beiden Ereignissen einkalkuliert.

Weiters wurde der zweijährige gleitende Durchschnitt des Zuwachses an neu fluoridierten Einwohnern und des Zuwachses an Krebstoten für den Zeitraum 1950 - 1969 berechnet und untersucht, ob ein Zusammenhang zwischen diesen beiden Variablen besteht. Damit werden einerseits Schwankungen der Variablen ausgeglichen und andererseits der Tatsache Rechnung getragen, dass im Falle eines Einflusses der Fluoridierung auf das Krebsgeschehen dieser selbst bei kurzfristigen Auswirkungen zeitlich nicht scharf begrenzt sein würde. Abb. 8 zeigt das Ergebnis, wobei hier nicht nur die Jahre der "Fluoridierungsschübe" berücksichtigt sind, sondern alle Jahre im beobachteten Zeitraum einschliesslich jener mit schwachen Fluoridierungszuwächsen.

Der Zusammenhang ist mit 99.998 % (F-Statistik) hochsignifikant. Die Regressionsanalyse ergibt: $b_0 = 4.511$, $b_1 = 0.339$, $R^2 = 0.728$, $F = 40.139$, $n = 17$. Die Jahre 1960/61 wurden als "Ausreisser" in die Statistik nicht aufgenommen, da durch die Aufnahme der Krebstoten von Alaska und Hawai in die amtliche Krebsstatistik bei der Differenzenbildung ein "Sprung" entsteht, der mit dem Beginn der Fluoridierung nichts zu tun haben kann, weil die Fluoridierung selbst dort schon viele Jahre früher eingeführt wurde. Nach dem obigen Ergebnis ist ein Neuzuwachs an Krebstoten von durchschnittlich 4500 jährlich unabhängig von der Zunahme an neu fluoridierten

Einwohnern und ein Neuzuwachs von ca. 3.4 zusätzlichen Krebstoten pro 10 000 neu fluoridierte Einwohner im zweijährigen gleitenden Durchschnitt zu erwarten.

ZUSAMMENFASSUNG

Fluoride sind von Natur aus in unterschiedlichen Konzentrationen im Trinkwasser enthalten. Der künstliche Zusatz von Fluoriden zum Trinkwasser in Fluoridierungsexperimenten eröffnet nun die Möglichkeit, die Relationen zwischen Trinkwasserfluoridierung, Krebs und Leberzirrhose zu studieren.

Es wurden offizielle Daten von 1949 bis 1969 aus den USA analysiert. Regressionsanalysen zeigen hochsignifikante Relationen zwischen der Rate der über das Trinkwasser fluoridierten US-Bevölkerung auf der einen Seite und der Krebstodesrate, der altersadjustierten Krebstodesrate, und der Leberzirrhose-Todesrate auf der anderen Seite.

In weiteren Analysen wurde die Möglichkeit eines Kurzeffektes der künstlichen Trinkwasserfluoridierung auf die Zahl der Krebstoten studiert, da die Einführung der Wasserfluoridierung eine plötzliche Änderung der Lebensbedingungen in den betroffenen Gebieten durch einen wohldefinierten Faktor bedeutet. Es wurde die Größe der Zunahme der Krebstoten in Relation zur Zunahme der fluoridierten Einwohner, basierend auf den authentischen Daten über die Wasserfluoridierung und die Krebssterblichkeit in den USA, analysiert. Es existiert ein hochsignifikanter Zusammenhang. Daraus ergibt sich, dass kurze Zeit nach Einführung der künstlichen Trinkwasserfluoridierung zusätzlich mehr als drei Krebstote pro 10 000 neu fluoridierte Einwohner erwartet werden müssen.

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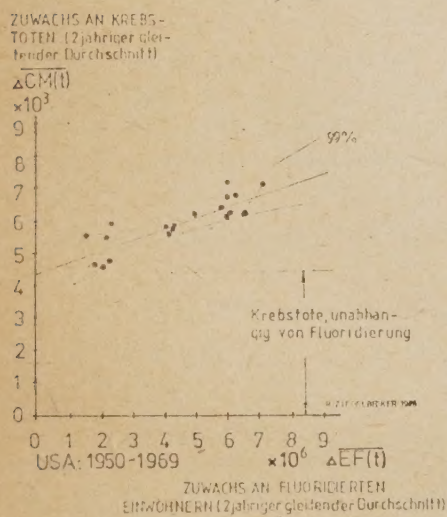


Abb. 8. Relation zwischen dem zweijährigen gleitenden Durchschnitt an neu fluoridierten Einwohnern und dem Zuwachs an Krebstoten 1950 - 1969 in den USA (x-Achse: $x \cdot 10^6$, y-Achse: $y \cdot 10^3$).

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Environmental risk factors in AIDS?

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The infection of humans by HIV viruses is a necessary but not sufficient cause of AIDS development. Kaposi's sarcoma (KS) has been reported in over 34 % homosexual men with AIDS but only in 6 % of AIDS patients from other groups. Chimpanzees as well as some people infected with HIV continue to live in good health. These facts as well as others indicate that in addition to HIV viruses, risk factors participate in the development of AIDS¹. Current results indicate that death of T4 (blood) cells typical for AIDS occurs after the integration of HIV viruses and then after the (second) activation of T4 cells. Many authors consider AIDS to be an autoimmune and/or hypersensitive (allergic) disease during which the autoimmune effect causes the disproportional destroying of T4 cells.² Factors favouring the integration and reproduction of HIV viruses in the organism can be rightly referred to as AIDS cofactors and those promoting the development of the autoimmune and/or allergic AIDS disease proper, as AIDS predisposing factors³ or aidsogens.

Differences in AIDS between the USA and Africa

From the facts that of Africans and Haitians who developed AIDS, a high fraction was tuberculous, LAMOUREUX et al.³ infer that the mycobacter, which causes tuberculosis, is a common AIDS predisposing factor in Africa and Haiti. Tab. 1 demonstrates that while in the USA the ratio of percentage HIV infected persons to percentage AIDS patient was 17, in Central African countries this ratio was 500 - 5000 in the same time. In blood sera sampled in 1970 in the town Kinshasa, Zaire, the mean percent fraction of HIV seropositive persons was virtually the same as in the USA in 1985 (i. e. 0.25 %), although in Kinshasa and anywhere else in Africa there was no AIDS epidemic in the 1970's. The factors significantly accelerating the conversion of latent HIV infection into manifest AIDS that occur in the living environment of Europe and especially of USA, can be denoted as civilization aidsogens.

Nitrate inhalants: One of the risk factors in AIDS?

Homosexual men in the USA often use nitrate inhalants, one of recreational drugs. Many researchers attempted therefore to find evidence in favour of the hypothesis that nitrite inhalants are an AIDS risk factor with KS incidence.¹ Fig. 1 indicates that a low nitrite intake lowers the AIDS incidence and higher nitrite doses increase it. The authors⁴ whose data are plotted in Fig. 1B conclude that these data fail to prove the fact that nitrites are an AIDS risk factor. However, since the curve in Fig. 1B has the shape of a Selye stress adaptation curve (resistance to a disease is first increased by small amounts of the noxa and only decreased by higher amounts - see also Fig. 1A), we suppose that still, nitrites are to be looked upon as a potential AIDS risk factor.

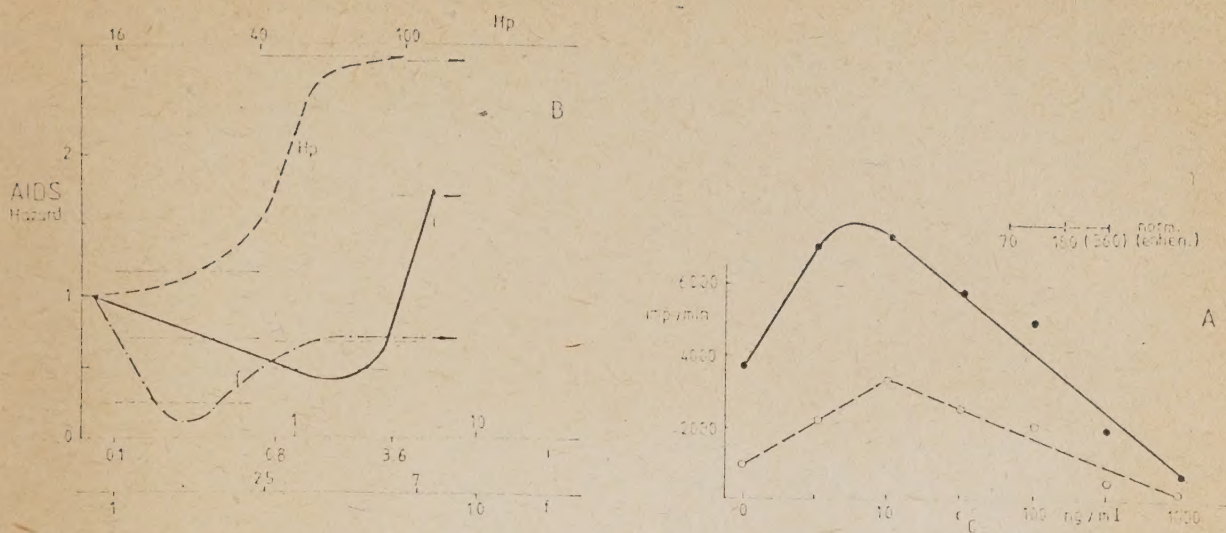


Fig. 1. Curves of "paradoxical effects" similar to a part of Selye stress adaption curve.

Panel B: influence of frequency f (in days per month the previous year) and intensity i (in sniffs per day) of inhalation of nitrate inhalants and influence of number of homosexual partners H_p (rate per 100 person-years of follow-up) on the relative hazard of development of AIDS in a cohort of 86 seropositive homosexual men⁴. Panel A: influence of cortisol concentration c_C on functional activity of peripheral blood lymphocytes of quinea pigs in imp/min; this data are a measure of the incorporation of 3H -uridine (1), and 3H -leucine (2) into mononuclear cells of Kon A¹⁵.

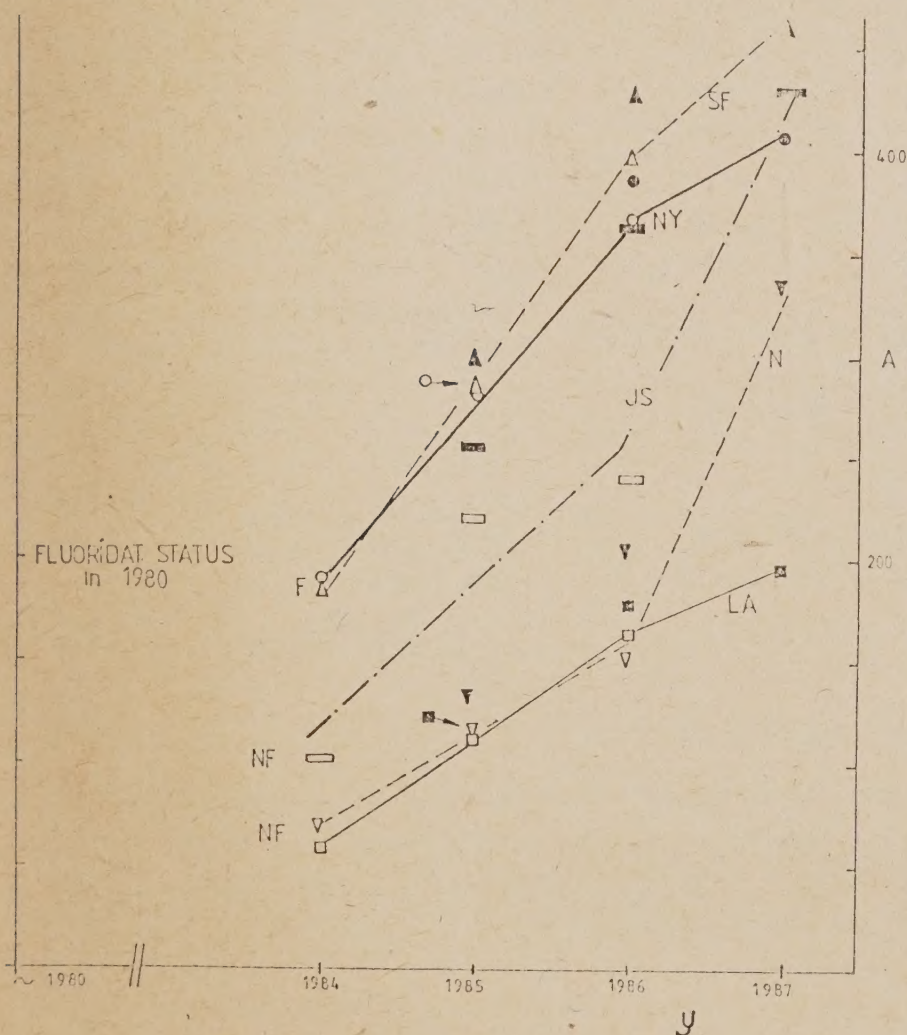


Fig. 2. AIDS cases per million of inhabitants A by years of diagnosis y based on the reports from 10/87⁹ (blank symbols) and 4/88^{9a} (full symbols) in San Francisco SF, New York NY, Los Angeles LA, Newark N, and Jersey City JC. In some towns without fluoridated water (NF) in 1980, e. g. in JC and N, fluoridation of the water was started after 1980, and in other towns as LA it was not started?

Tab. 1. Relationship of HIV seropositivity and AIDS incidence in "developed" countries and in central Africa. Seropositivity in "developed" countries is the seropositivity of blood donors before high risk groupes screened out⁵, and in Africa the seropositivity in the general population or in pregnant^P women⁶ (other literature quoted). AIDS incidence is based usually on AIDS cases reported to WHO to 13th March 1987; in Nigeria to 5/1987¹⁰; data for Kinshasa are related only to Kinshasa in 1984¹¹.

	HIV seropositivity		AIDS incidence	Relationship	Oldest known seropositivity
	% (A) in Yr		% (B)	A/B	%/in Yr
"developed" countries					
France	0.495	1984	0.002	248	
Spain	0.23	1985	0.001	230	
USA	0.225	1985	0.013	17.3	
Brazil	0.13	1985	0.001	130	
Finland	0.005	1985	0.0003	16.6	
mean (range)				128 (15-250)	
Central African countries if					
>100 subjects analysed					
Uganda (Kampala)	15, 14 ^P	1985	0.005	2900	
Zambia (Lusaka)	9 ^P	1985	0.004	2250	
Congo (Brazzaville)	5	1985	0.001	4000	
Ctr. Afr. Rep. (Bangui)	4	1985	0.008	500	
Kenya (Nairobi)	2 ^P	1985	0.0005	4000	
Cameron	1	1985	0.0002	5000	
Tanzania (4 towns) ¹²	5.0 ^P	1986	0.005	1000	
town Kinshasa, Zaire ¹¹	8 ^P	1985	0.017	470	0.2/1970 ⁷
mean (range)				2800 (500-5000)	
Central African countries if					
<100 subj. anal.; (/n) the n. of subj. anal.					
Ivory Cost (Abidjan)	5 ^P (/42)	1986	0.001	5000	
Uganda (West Nil)	1.4 (/71)	1985	0.005	280	67/1972 ⁸
Nigeria (Lagos)	8 (/65)	1987	7x10 ⁻⁶	10 ⁶	
and if all AIDS cases would be in Lagos			0.0004	20000	
(range)				(200-10 ⁶)	

Potential civilization aidsogens: Fluorides one of them?

Potential civilization aidsogens may be substances such as (I) having an immunomodulating effect (on animals involved in the experiment); (II) their amounts particularly in the diet of people in developed countries has been increasing; and (III) their higher intake correlates with a higher AIDS incidence, evidenced by epidemiological data.

Tab. 2. AIDS cases by date of diagnosis in 20 standard metropolitan statistical areas (SMSA) of residence ordered according to AIDS cases per million inhabitants in 1986 (data according to⁹ or in 1987 according to^{9a}). F-number (e. g. 52) fluoridated from 1952, NF-not fluoridated, np-naturally partly fluoridated, d-discontinued fluoridation many years ago (1954) - taken as NF (quoted according to the fluoridation census 1980¹³ and¹⁴, ° not quoted in¹⁴)

SMSA of residence No	Fluori- dation start year	Populat. in 1980 mill.	AIDS cases/10 ⁶ inhabitants in the year				AIDS cases cumulative in		
			1984	1985	1986	1987	absol. 10/87	No 10/87	No 4/88
1 San Francisco, CA	F52	3.259	185.0	284.1	398.5	460.6	4096	2	2
2 New York, NY	F65	9.122	186.6	279.5	366.8	408.3	10924	1	1
3 Jersey City, NJ	NF [°]	0.562	103.2	219.0	252.7	425.2	496	16	15
4 Miami, FL	F52	1.634	115.0	170.7	212.4	252.7	1183	6	7
5 Fort Lauderdale, FL	NF [°]	1.028	56.4	120.6	180.9	277.2	549	13	13
6 Huston, TX	npF82 ¹⁶	2.918	60.0	112.7	176.5	231.3	1440	4	4
7 Los Angeles, CA	NF	7.484	59.3	112.2	164.4	195.2	3627	3	3
8 Newark, NJ	NF	1.972	70.5	115.1	150.1	338.7	1047	8	6
9 Washington, DC	F52	3.065	45.0	106.0	130.5	215.3	1273	5	5
10 Atlanta, GA	F69	2.031	34.5	79.8	122.1	163.0	687	11	11
11 San Diego, Ca	dNF	1.864	23.6	60.6	107.8	163.6	541	14	14
12 New Orleans, LA	F74	1.194	41.9	71.2	105.5	177.0	362	19	18
13 Dallas, TX	F66	2.977	27.5	55.4	98.1	182.7	826	10	9
14 Seattle, WA	F69	1.611	32.3	59.0	86.9	143.3	412	17	17
15 Denver, CO	F54	1.625	22.8	49.0	75.7	123.1	387	18	19
16 Boston, MA	F78	2.765	27.8	53.1	74.9	114.3	684	12	12
17 Nassau-Suffolk, NY	NF [°]	2.612	25.3	43.8	67.8	73.9	513	15	16
18 Philadelphia, PA	F54	4.724	23.9	42.1	60.8	92.9	853	9	10
19 Anaheim, Ca	NF [°]	1.937	20.1	35.6	54.7	-	350	20	-(>20)
20 Chicago, IL	F56	7.105	17.4	31.5	50.8	76.6	1069	7	8
Baltimore, MD	F52	2.17	-	-	-	98.6	-	-(>20)	20
Sum 20 SMSA (1 - 20)		61.489 (27%)					31324 (73%)		
USA total		230.115 (100%)					42965 (100%)		
$\bar{x}_F$ for 1, 2, 4, 9, 10	F58		113.2	184.0	246.1	300.0			
$\bar{x}_F$ for 3, 5, 7, 8	NF		72.3	141.6	187.0	309.1			
$\bar{x}_F$ for 12-14, 18, 20	F64		27.7	51.7	79.0	130.0			
$\bar{x}_F$ for 11, 17 and ⁺ 19	NF		23.0 ⁺	46.6 ⁺	76.8 ⁺	118.7			

Tab. 3. Differences in AIDS cases/10⁹ inhabitants between fluoridated (F) and notfluoridated (NF) standard metropolitan statistical areas (SMSA) of residence in Tab. 2 tested by means of the t test. No 1, 2 and 7, i. e. San Francisco, New York and Los Angeles are the three SMSA where AIDS was firstly recognized in the year 1981.
xxx - P < 0.005, xx - P < 0.01, x - P < 0.05, P one-tailed.

No of SMSA of residence			values of t test and one-tailed P			
F	versus	NF	1984	1985	1986	1987
1, 2		7	91.3 ^{xxx}	42.5 ^{xx}	7.95 ^x	5.28
1, 2, 4		3, 5, 7, 8	3.83 ^{xx}	2.37 ^x	2.52 ^x	0.83
1, 2, 4		3, 5, 6, 7, 8	4.45 ^{xxx}	2.81 ^x	2.92 ^x	1.13

Fluorides seem to be among such substances. Their ability to increase or lower the immune resistance has been ascertained by several authors. The fluoride content of diet in developed countries has been increasing as a consequence of the use of fluorophosphates as soil fertilizers. Moreover, in many towns in the USA their inhabitants receive fluorides in fluoridated drinking water. Tab. 2 shows the annual increase in AIDS incidence per million inhabitants in 20 standard metropolitan statistical areas (towns) in the USA, involving 3/4 of all AIDS cases in this country, for the years 1984 to 1986 (and preliminarily also for 1987), along with the fluoridation status of these towns in 1980. Naturally, the first prerequisite for AIDS spreading in a town is that HIV infection has been brought there. This is not related with the fluoridation status, and, hence, both higher and lower increments are observed in 13 towns with fluoridated water in comparison with 7 not fluoridated towns. But we can compare 3 towns where simultaneously the first AIDS cases were observed. In this case we find the relative AIDS incidence significantly higher ($P < 0.05$ or even 0.005) in San Francisco and New York, with fluoridated water, than in Los Angeles where fluoridation was not adopted. This conclusion also applies to a group of 7 and 8 towns with and without fluoridated water, with the highest relative AIDS incidence values (with 50 % of the total AIDS cases in the USA); for this groups the factor of different time of starting HIV infection spreading is not so large to obscure the effect of AIDS risk factors as in the case of 20 towns. See Fig. 2 too. Fluorides can be considered for as the first concrete potential environmental aidsogen. The easier development of AIDS in certain regions in comparison with other ones could be a bio-indicator of the pollution of the regions.

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